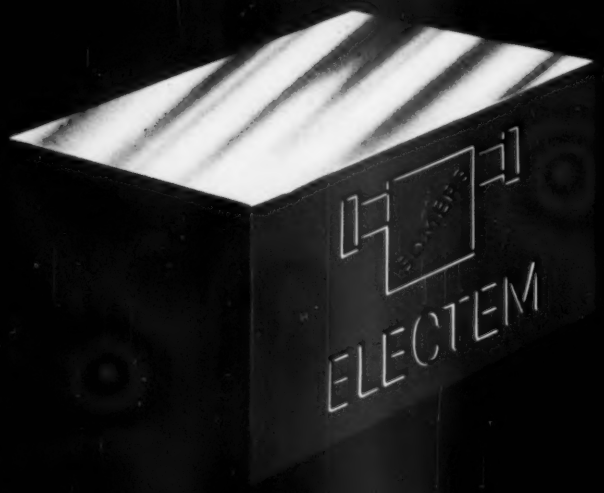
metal atment

Vol. 25 : No. 151 APRIL, 1958 Price 2/6

MASSEY

ELECTEM
DIE BLOCKS



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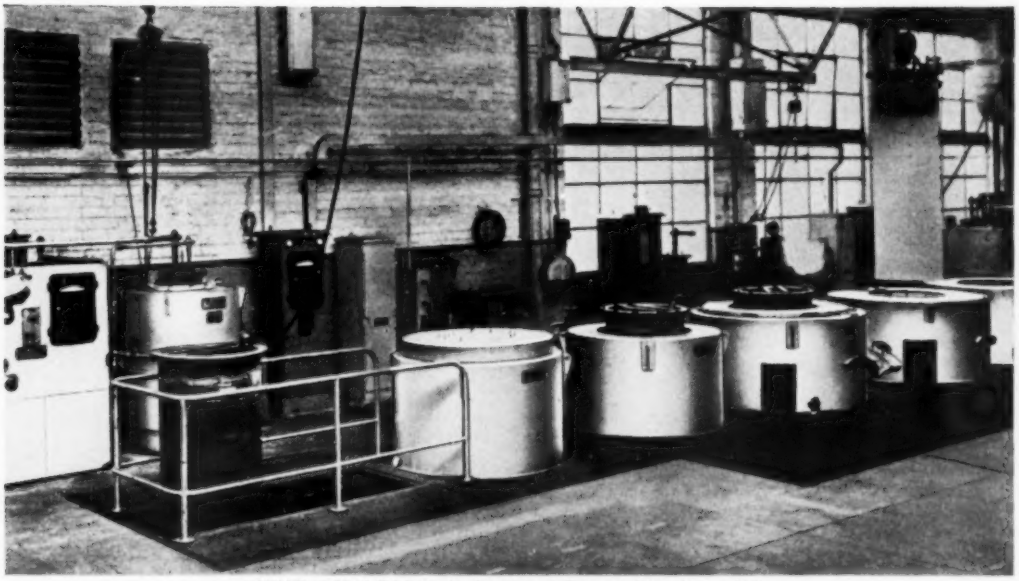


Wild-Barfield "P.T.G." Gas Carburising installation at Albion Motors Ltd.

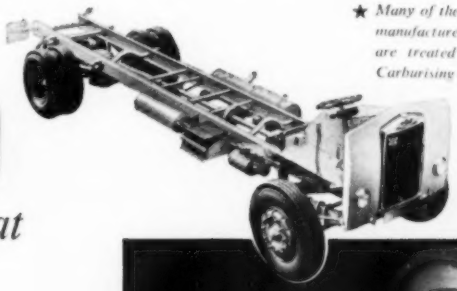
They rely on

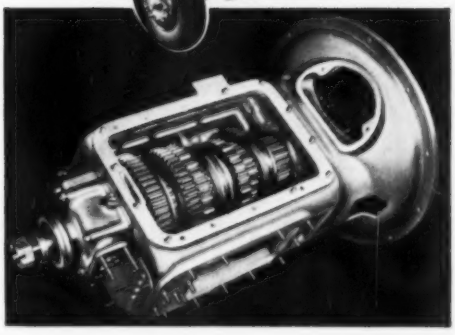
WILD BARFIELD

Gas Carburising at

Albion
MOTORS LIMITED

★ *Many of the components used in the manufacture of Albion motor vehicles are treated in Wild-Barfield Gas Carburising equipment.*





Precise control of depth and type of case is afforded by both Wild-Barfield gas carburising processes—the "P.T.G." and "Carbodrip" drip feed. By these methods carburising proceeds at almost the maximum theoretical rate. We will be glad to send you full details on request.

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WB 54

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Hydraulic press brake with horn extension, 10′ × ¼″ capacity.

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The Eldair series of mechanical press brakes handles light and medium plate sizes up to 12′ × ⅛″ M.S. with a forming pressure up to 110 tons. They are extremely powerful and smooth in operation and fitted with a multi-plate clutch and automatic brake for inching.

Eldair hydraulically operated press brakes are entirely self-contained and designed to provide smooth single or continuous stroking action. They are available in pressures up to 700 tons and a bending capacity up to 14′ × ¾″ M.S. The stroke is adjustable to suit the application with full pressure available at any position.

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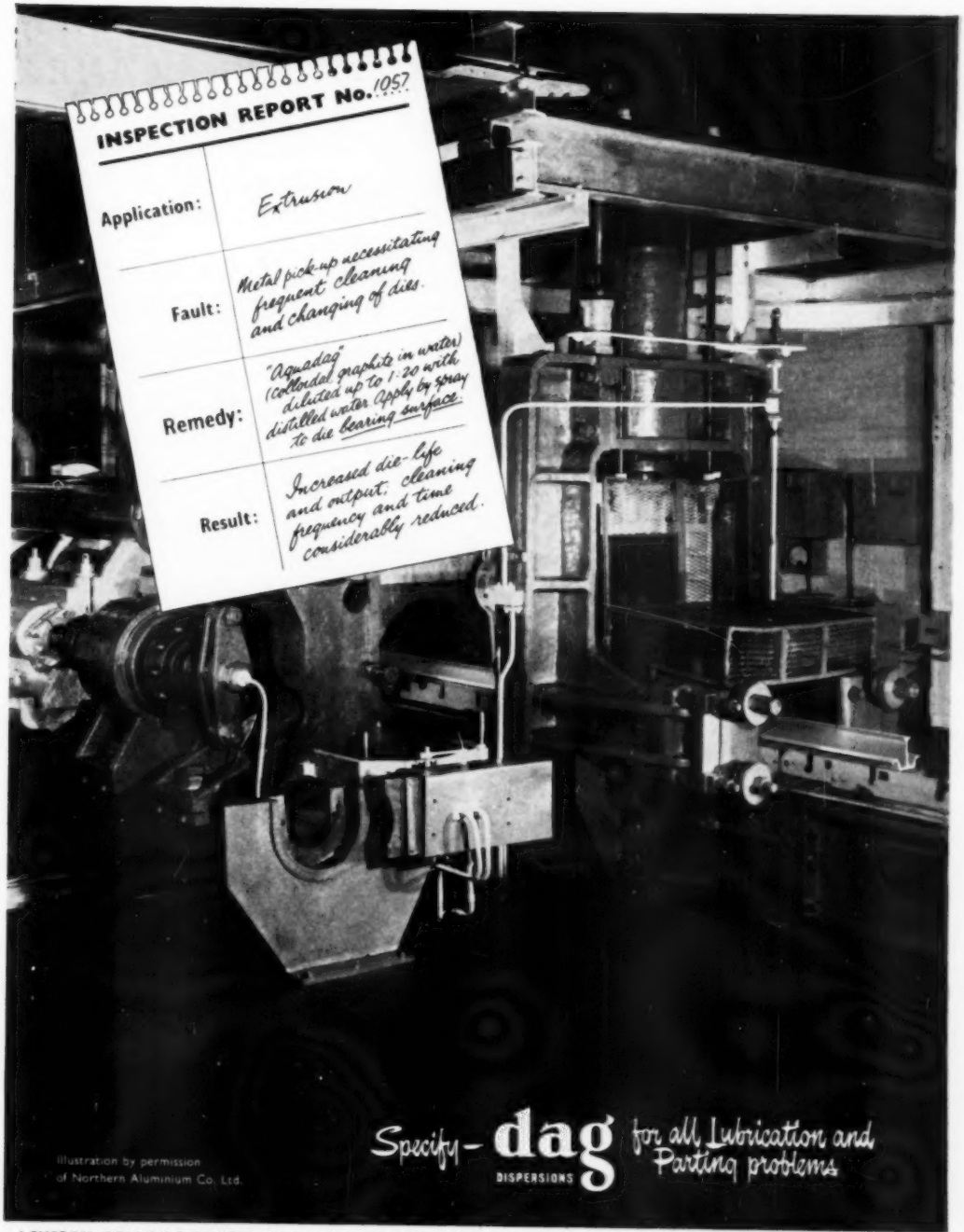
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Application: Extrusion
Fault: Metal pick-up necessitating frequent cleaning and changing of dies.
Remedy: "Aquadag" (colloidal graphite in water) diluted up to 1:20 with distilled water. Apply by spray to die bearing surface.
Result: Increased die-life and output; cleaning frequency and time considerably reduced.
Specify - dag DISPERSIONS for all Lubrication and Parting problems
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Do you allow swarf to be transported with valuable cutting oils and compounds dripping on to your factory floor—are you getting the highest price for your swarf?

★BROADBENT PLANNED SWARF DISPOSAL answers these problems—cutting oils and compounds are reclaimed, production costs are cut; clean swarf demands high prices and costs less to transport and, furthermore, you KEEP YOUR FACTORY CLEANER

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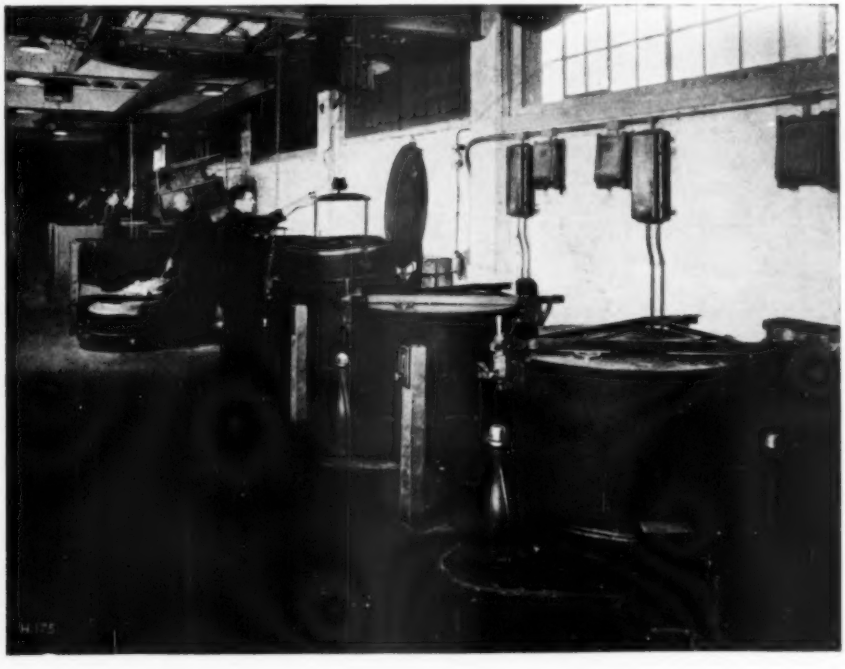
Phone 5520/5

★ This installation of our type 4(28) suspended direct electrically driven extractors removes the oil from medium steel swarf. The basket, loading bunker and overhead runway are illustrated in the background.



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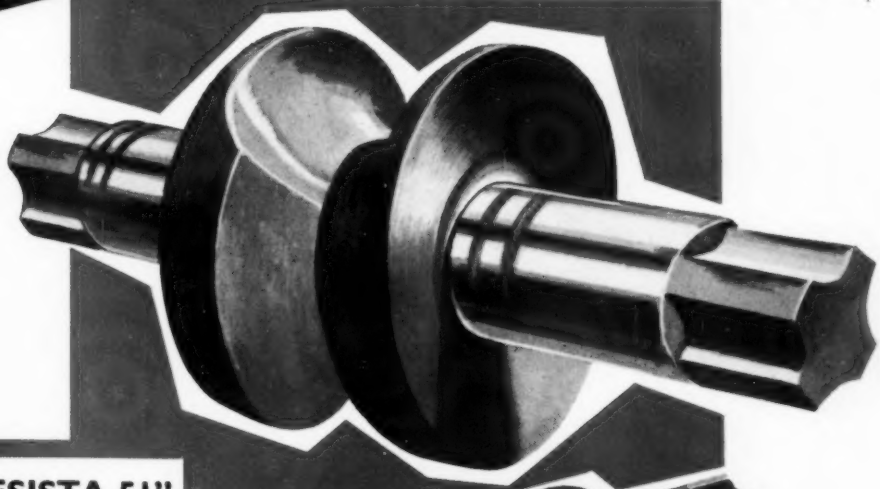
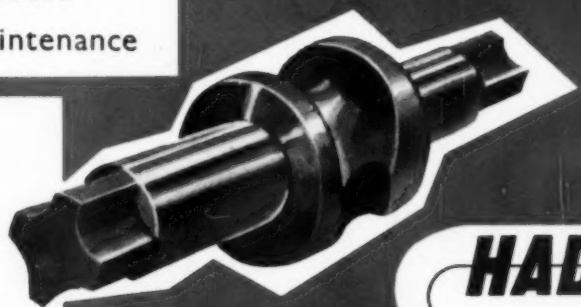
SPECIAL ALLOY STEEL PILGER ROLLS



"RESISTA 51" assures greater output and reduced maintenance

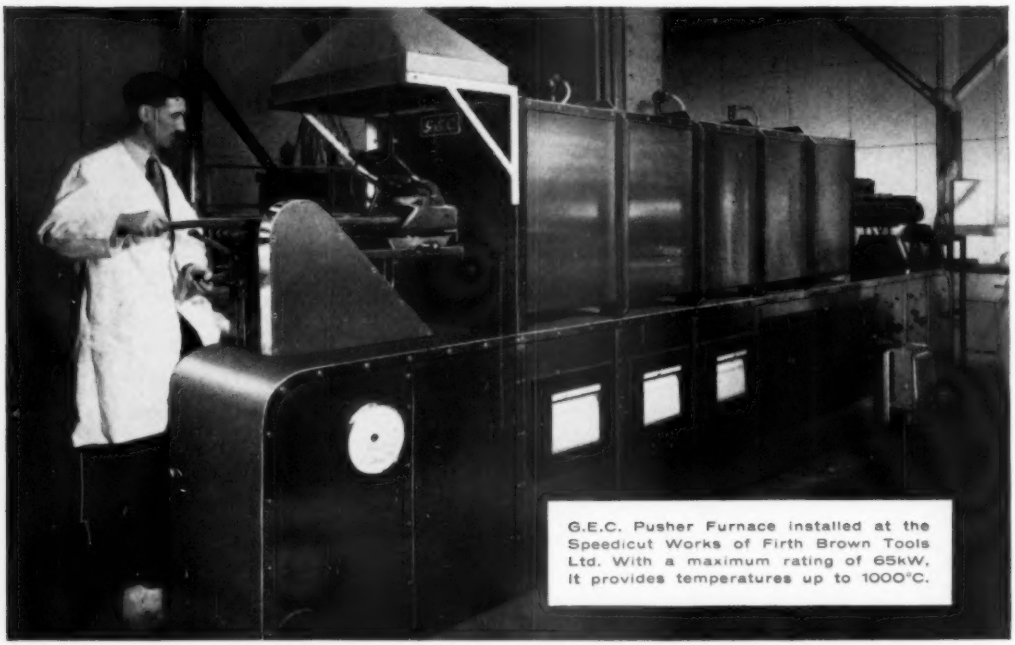


HADFIELDS SHEFFIELD

HADFIELDS LTD., EAST HECLA WORKS, SHEFFIELD, ENGLAND.

Firth Brown Tools Ltd use a G.E.C. Continuous Pusher Furnace

for Pre-sintering Tungsten Carbide Tool Tips



G.E.C. Pusher Furnace installed at the Speedicut Works of Firth Brown Tools Ltd. With a maximum rating of 65kW, it provides temperatures up to 1000°C.

For efficient process heating use

The G.E.C. designs and manufactures many kinds of continuous furnaces to provide precise heat treatments and to give maximum outputs with the minimum of attention. The pusher furnace can be used for most heating processes and is particularly suitable for handling heavy charges. The furnace illustrated here is used to process tungsten carbide in a hydrogen atmosphere. It has its controls, switchgear and transformers built in to save floor space and is encased in polished stainless steel sheet to present a clean appearance.

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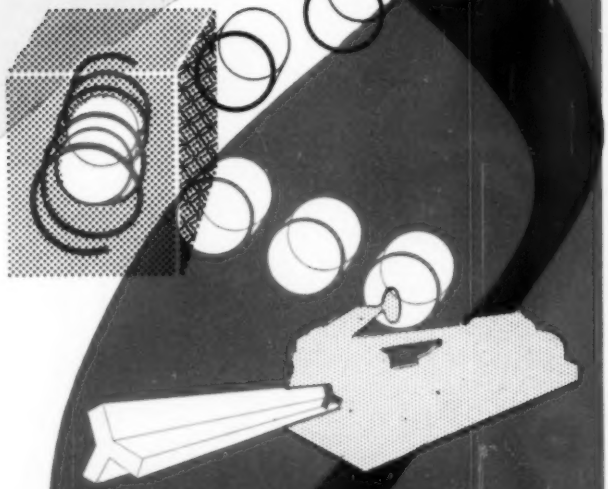

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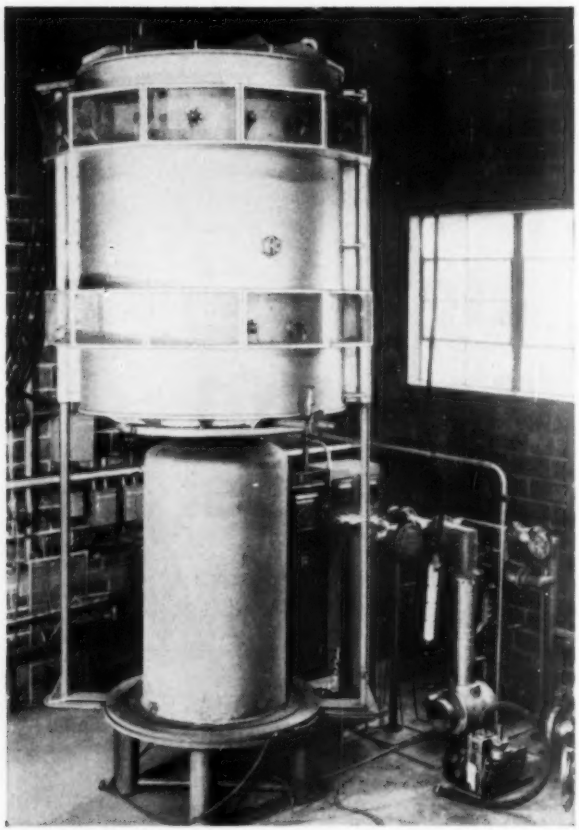

This model has a uniform hot zone 36" dia x 36" high and ultimate vacuum of less than 1 micron.

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The experience of the National Research Corporation who have built more than 100 vacuum furnaces, now in successful operation, and the facilities in Britain of Wild-Barfield combine to offer unsurpassed vacuum resistance furnaces of the horizontal muffle, pit and bell types with diameters from 2 to 54 inches.

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NRC3

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Our own design giving excellent performance under severest conditions.

Top and bottom ejectors
air operated, adjustable to suit all requirements.

Operation of air ejectors
can be limited to every second or third stroke as required.

Calibrated table adjustment
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Telephone Weybridge 3816. Associated with Electric Furnace Co. Ltd., and Electro-Chemical Engineering Co. Ltd.

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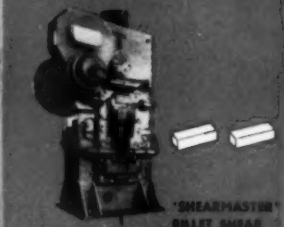
WILKINS & MITCHELL



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'ROLLMASTER' FORGING ROLLS

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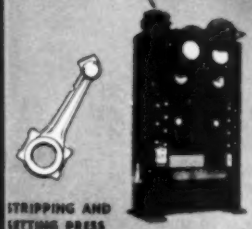

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Wilkins & Mitchell Forgemaster High Speed Forging Press, 1,500 tons capacity, and Clipping and Setting Press in production on precision forgings for Messrs. Garringtons, Bromsgrove.

600 ton capacity Stripping and Setting Presses in the Works of Messrs. Clydesdale Stamping Co. Ltd., Netherton.

Wilkins & Mitchell Stripping and Setting Presses make multiple operations in line-flow production a practical proposition. This increases the productive capacity of both drop hammer and forging press and ensures:

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- reduced component cost

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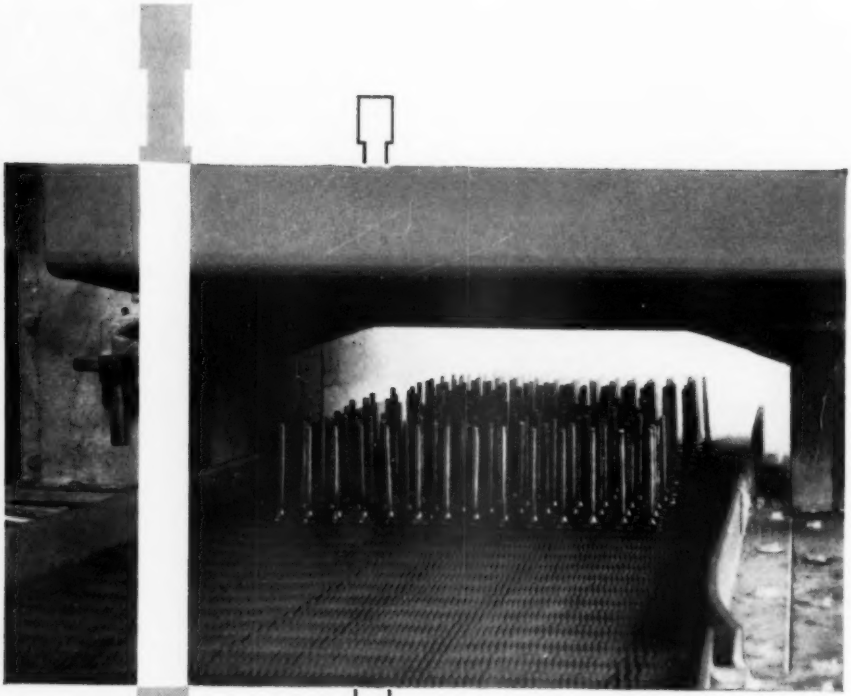

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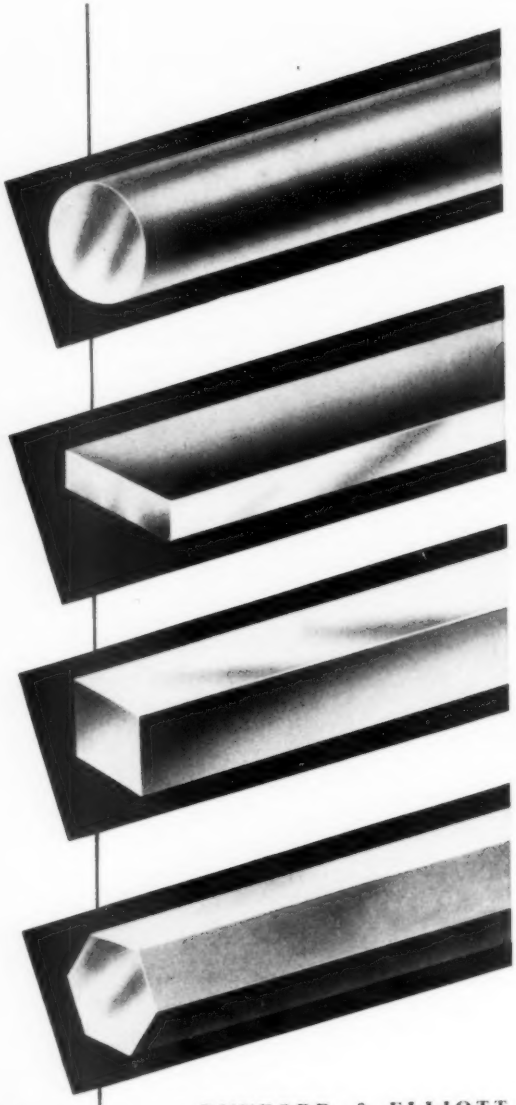

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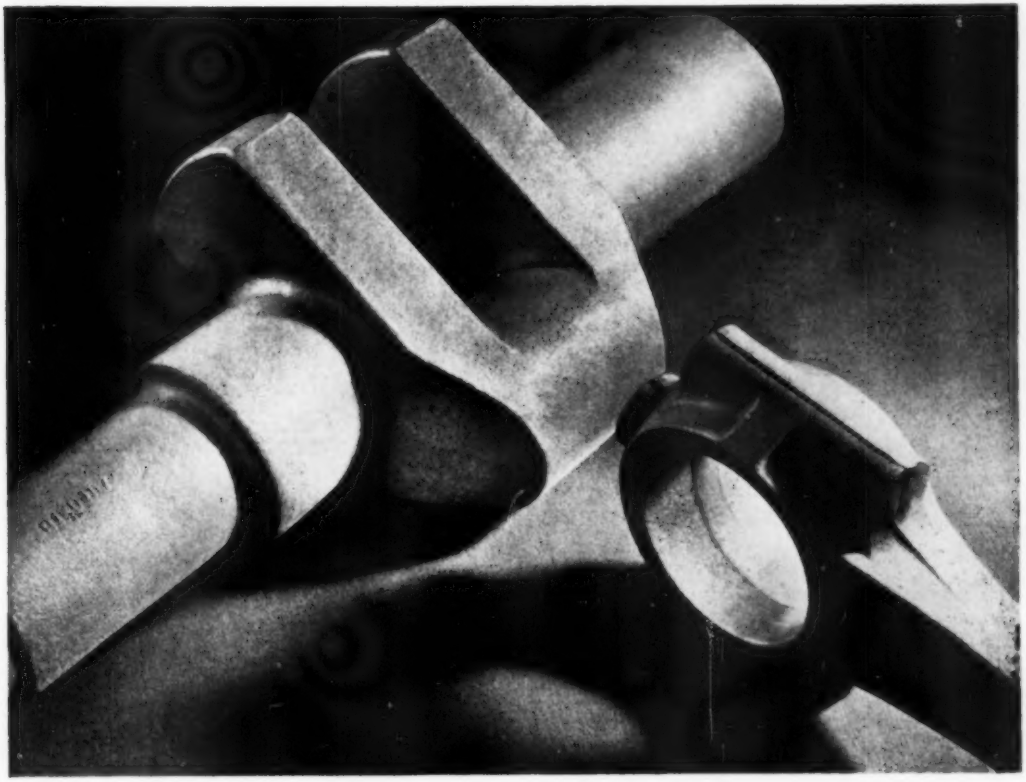

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- **Delivery ex stock.**

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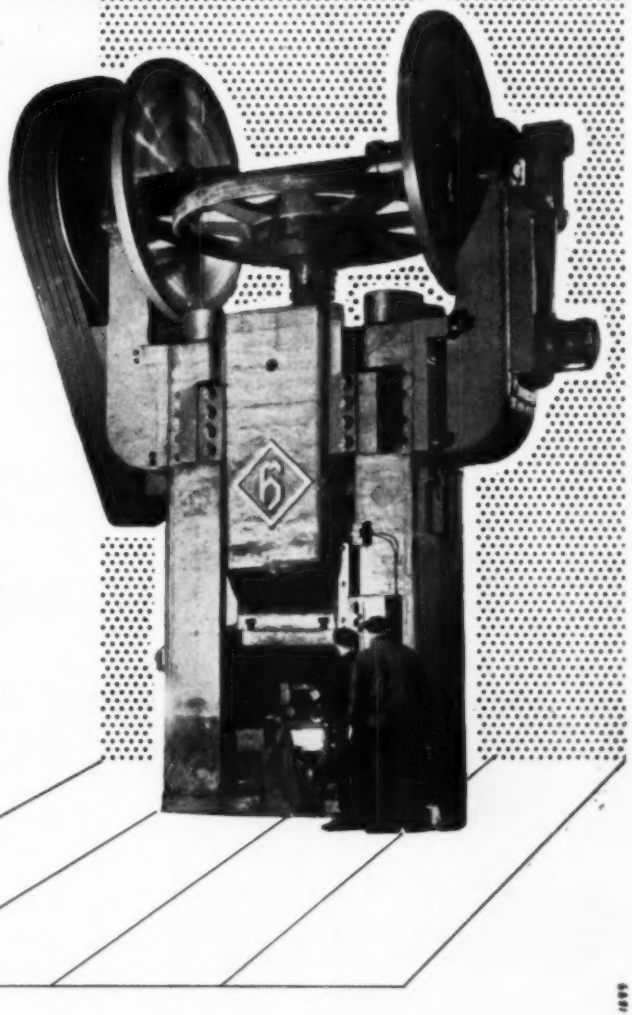
With push button Programme Control



Producing heavy pipe flanges **12" dia. bore x 19" o/d.**, from billets, in one heat and three blows.

The press is equipped with push button programme control to give blows of different strength automatically for one operating cycle.

Maximum nett energy rendered is approx. 195,000 ft./lb.

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The Chambersburg Ceco-Drop is an improved-type Drop Hammer providing more blows per minute and closer tolerances in the forgings.

Maintenance costs are reduced due to fewer and more durable working parts.

The size available for early delivery is the 3,000 lbs and full details of specifications are contained in a comprehensive catalogue which will be sent on request.

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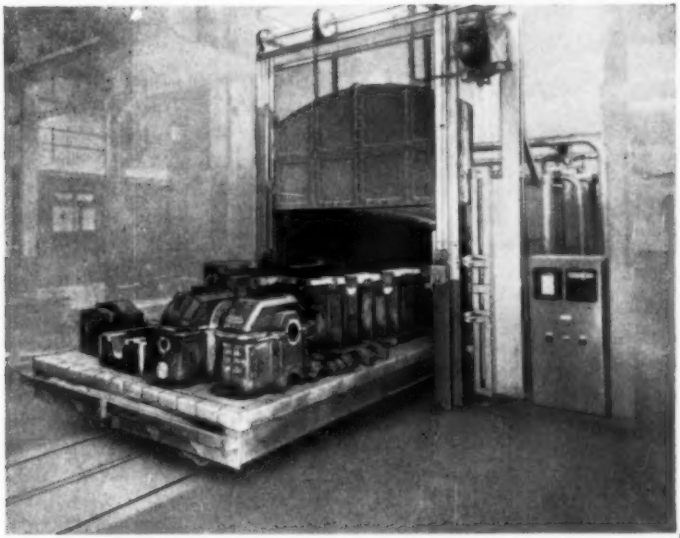
"NEWSTAD" Recirculation Furnaces . . .



The rapid development of heavy fabrications to replace castings has led to the introduction of our Recirculation Furnaces for stress relieving and preheating. If required these furnaces can be supplied to cover the whole temperature range of 500° to 1100° C.

Our illustration shows one of our furnaces at Messrs. David Brown Industries Ltd., used to heat treat fabrications for their famous Radicon gear boxes.

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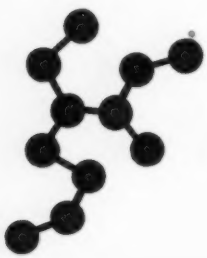

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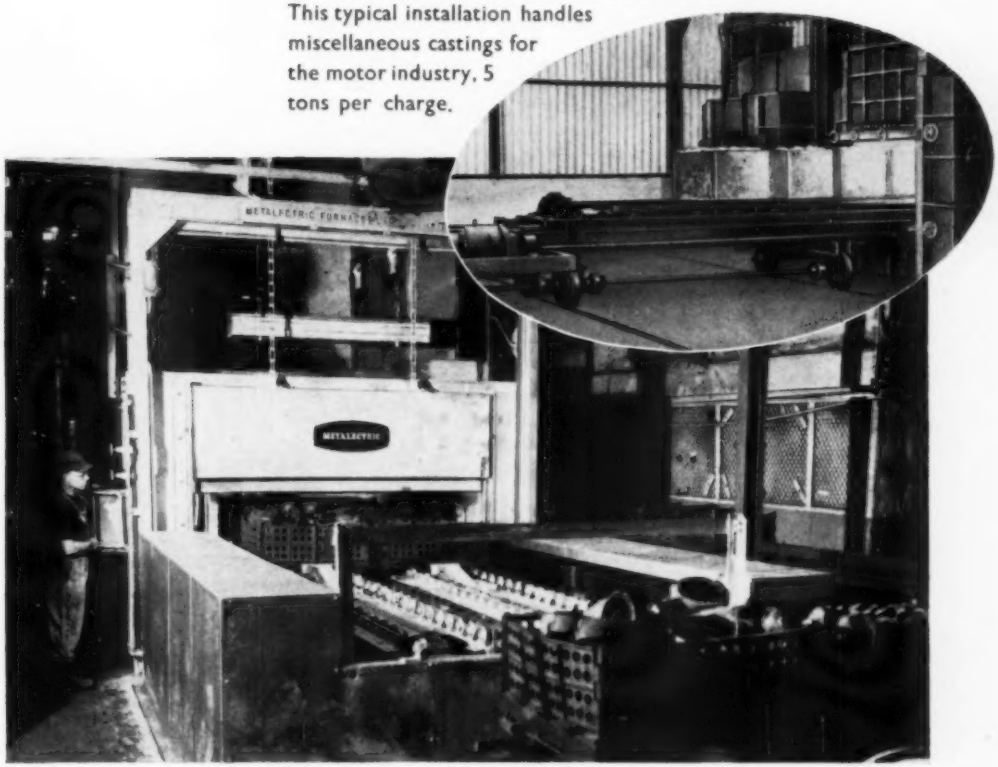
MALLEABLIZING

FERRITIC MALLEABLE

may be produced in batch or continuous furnaces. This typical installation handles miscellaneous castings for the motor industry, 5 tons per charge.



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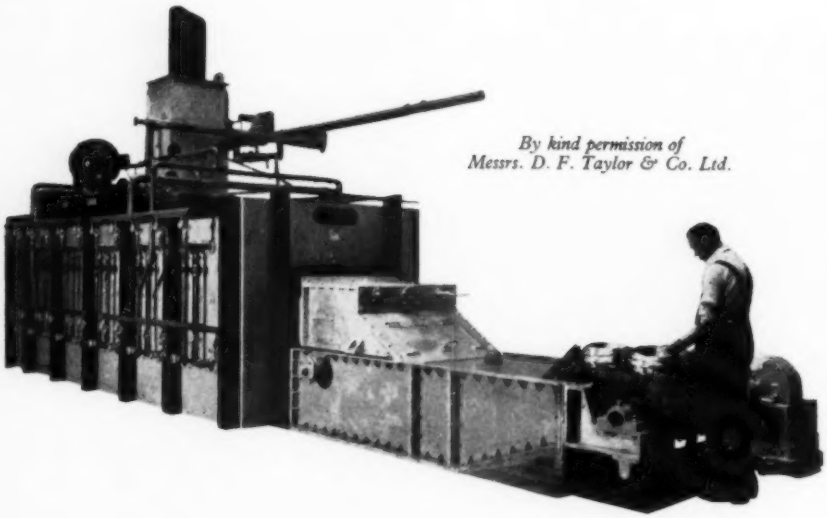

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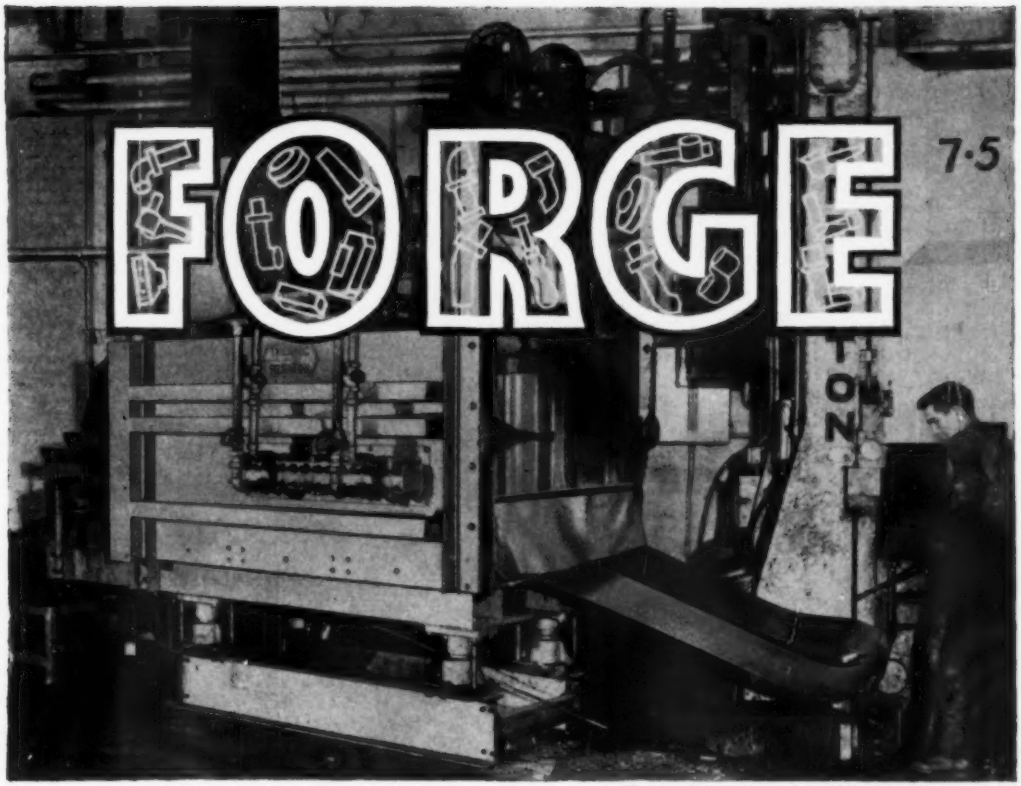

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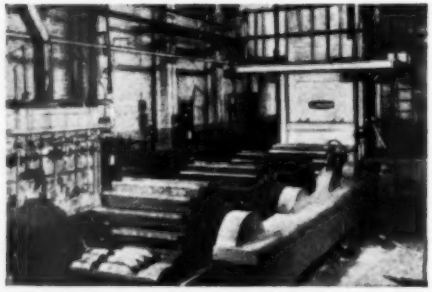

Discharge side of vertical conveyor furnace with special washing and testing tanks in foreground.

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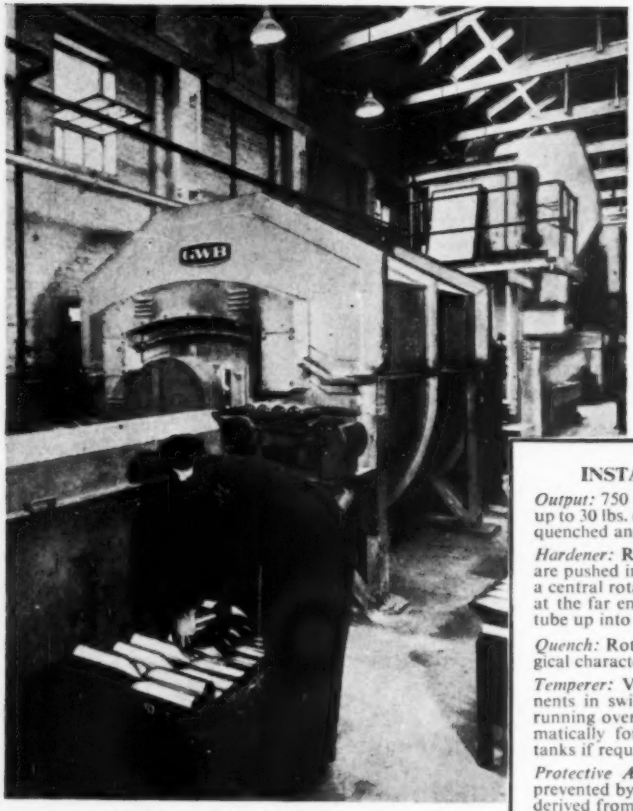

Charging end of rotating tube pusher feed hardening furnace: vertical conveyor tempering unit in background.

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Quench: Rotating oil quench to obtain required metallurgical characteristics.

Temperer: Vertical Conveyor type carrying the components in swivel mounted baskets slung between chains running over driven sprockets. Discharge effected automatically for further processing in continuous testing tanks if required.

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GWB 17

April 1958

Vol 25, No 151

Metal treatment

and Drop Forging

Editor D. J. O. BRANDT B SC, A R S M, F I M

Assistant Editor F. D. GRIMMER

Advertisement Manager J. M. DICKIE

Production Manager R. J. LOVELL

Publisher H. J. DWYER

Scottish Area Manager T. H. SMITH

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President J. H. SWAIN

Director A. L. STUART TODD, M A, J P

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Bewilderment

THIS journal is primarily devoted to the working and treatment of metals; general and economic matters are not therefore our immediate concern. Nevertheless, the working and treatment of metals are both industrial processes of fundamental importance and, since all industrial activity in the Western world is essentially governed by considerations of economics and finance, we are not perhaps unduly presumptive in making a few remarks on the subject.

In saying this the very last impression we wish to give is that we are laying any claim to expert knowledge—far from it. But, on the other hand, we cannot help feeling that it would make very little difference to the situation generally if we did make this specious claim, for it seems that the most obvious and disturbing feature of the present economic state of the world is not so much the situation itself, as the extraordinary failure of economists and financial pundits generally to reach any sort of agreement. Is the danger still inflation, or are we on the verge of serious deflation ? Do we, therefore, continue to restrict both demand and investment, or should taxation and high interest rates both be allowed to ' ease off ' ? The Government's ' Economic Survey ' comes down heavily in favour of the former, but that does not mean that such an analysis has met with uncritical acceptance and approval.

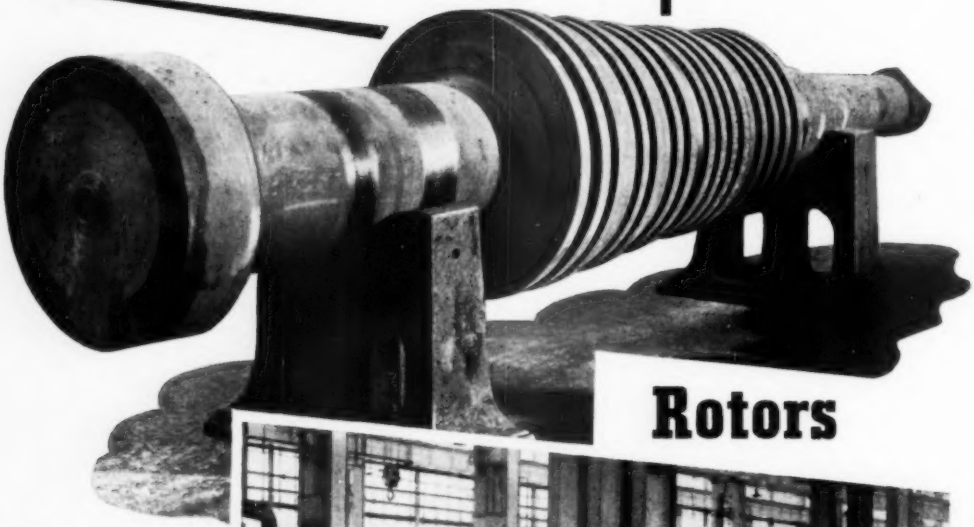
However, in the midst of this confusion of thoughts and words, there is one fact which stands out to hearten all those connected with the supply and fabrication of metals, and that is the remarkably good results which have been achieved in the past year by Britain's motor industry. At a time when the rest of the nation's industry has to report cut-backs in production, some of quite considerable magnitude, the production and sale of motor cars and commercial vehicles has remained practically on an even keel.

As we write this leading article, the news has just arrived of the remarkable success of British cars at the International Motor Show in New York. This is an effort which calls for further congratulation and yet, while we would be the last to withhold congratulations when they are due, we cannot help feeling a little more bewildered, for we were under the impression that something looking unpleasantly like the beginnings of a serious trade slump was appearing in the U S A. Can we, in other words, rely on holding this market ? Are we not in danger of seeing it contract and die on us before very long ?

As we have already pointed out, we do not claim to possess any economic expertise and certainly we do not pretend to be able to suggest any ' sovereign remedies.' But of this we are certain—in the eyes of the ' uncommitted ' nations of the Afro-Asian continents the Western system of ' free enterprise ' economy is on trial. If the worst happens, and the American and Western European areas sink into the kind of industrial and commercial stagnation experienced in the early 1930s then the men of the Kremlin will extend their empire without the necessity of hydrogen bombs or even of calling-up a single extra soldier.

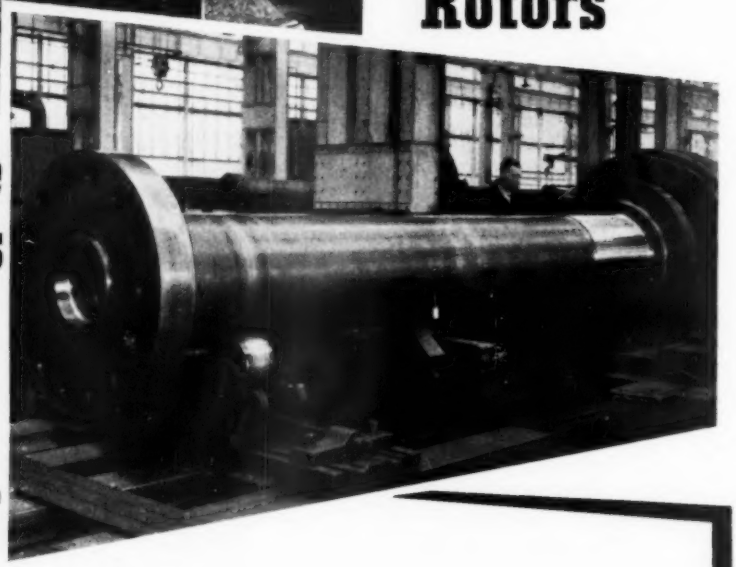
By the time these words appear in print the 1958 Budget will have been made public. We fervently hope that it will contain some words of wisdom and guidance to ease our present mood of bewilderment.

Steel Forgings



Rotors

Turbine shafts



ESC

ENGLISH STEEL FORGE AND ENGINEERING CORPORATION Limited

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Spark machining of forging dies

We are glad to be able to publish the following slightly abbreviated translation of an article by M. René Chevallier, issued by the Syndicat National de l'Estampage et de la Forge, France, and are grateful to them for permission to do so. The author indicates the new possibilities offered by the process of spark machining especially as regards the making and repair of dies

THE ORIGINS of electric-spark machining go back a long time, for most writers trace them to observations made by Priestley in the 18th century on the effects of an electric spark jumping between a metal point and a metal surface. The credit for envisaging the industrial potentialities of the process belong to the Lazarenkos, who established the fundamental circuit which bears their name. Amongst the numerous investigators and organizations who, working along parallel courses in various countries, subsequently developed and improved electric sparking, it is appropriate to give a special place to the Centre National de la Recherche Scientifique, Paris, which has taken out a number of patents. The licence for these patents is exploited by Société Française Languepin and by Compagnie Compteurs et Manomètres de Liége, which builds the Elektra machine.

Whilst there is still the possibility of significant improvement resulting from laboratory research, industrial exploitation has begun and many technical problems have already been solved.

The general term 'electric-spark machining' is understood as comprising a number of related processes corresponding to a variety of requirements.

It is thus that, for the removal of broken taps, one of the earliest applications of the process in industry, use is made of a high-intensity current at low voltage. The electrode must touch the piece requiring to be removed so as to give a start; afterwards it is drawn back, forming an arc. For repetition work—corresponding to classical smoothing operations, for example—the electrode-tool, consisting of a metal disc, as well as the workpiece, is immersed in an electrolytic bath.

The author proposes to enlarge only on the process and equipment for cutting the impressions required in dies for blanking and stamping.

Principles

The workpiece constitutes the positive electrode, and the tool the negative electrode; the latter will be simply called 'the electrode.' These are immersed in a dielectric bath whose function is partly to smother the sparks rapidly and thus to prevent an arc from building up; in addition it ensures cooling and facilitates the carrying away of the loosened particles. The shaping of the workpiece is effected by the extremely rapid successive action of the sparks, which each detach a very tiny particle of the metal. The sparks can be produced at a variable rate which is a function of the selected setting.

The power consumption varies according to the type of machine and the chosen rate of operation, but remains comparable with that of a traditional milling machine. The direct utilization of electricity makes possible an exceptional output with low fabrication times.

Equipment

As remarked previously, spark machining is applicable to a wide variety of work. The author will here content himself with giving details of machines specially adapted to the cutting of die impressions.

These machines comprise the following main parts: (1) A cabinet or stand for the electrical gear, (2) an electrode-carrying arm with upward or downward motion actuated by a servo-motor operating through a reduction gear, (3) a table and equipment for holding and controlling the dies, and (4) a bath containing the dielectric liquid in which the workpiece is immersed and a system for circulating, cooling, pumping and filtering this fluid.

Some of these machines have been built by making use of parts of existing machine tools of traditional pattern. Thus, a Sparcatron head of British origin has been mounted on a drilling-machine column. The Qualitex-Usimu machine, as well as the Elektra machines from Belgium, the British Wickman-Erodomatic and the Swiss-made Eleroda (Ateliers des Charmilles) have the electrical equipment incorporated in the stand.

It must be clearly understood that, in default of adequate equipment, only the smaller dies have so far been formed by spark machining. This is why

Institute of Metals

Golden Jubilee spring meeting

THE INSTITUTE OF METALS is holding its 1958 Golden Jubilee spring meeting in London from April 29 to May 2. The scientific and technical sessions and lectures will be open to non-members as well as to members of the institute and tickets of admission will not be required. Attendance at the social functions and visits, however, will be restricted to members of the institute and their guests and to official delegates.

The Golden Jubilee Banquet of the Institute of Metals will be held, under the Presidency of Marshal of the Royal Air Force, Lord Tedder, in the Great Room of Grosvenor House, Park Lane, London, W 1, on Thursday, May 1. The principal guest will be Lord Hailsham, president of the council, accompanied by Lady Hailsham. He will propose the toast of the Institute of Metals and the non-ferrous metal industries.

Tickets, price two guineas, may now be obtained from the Secretary of the Institute, 17 Belgrave Square, London, S W 1.

Some of the events are as follows:

APRIL 28
Golden Jubilee Lecture, by Prof R. S. Hutton, 8 15 p m at the Royal Institution, Albemarle Street, W 1.

APRIL 29
Annual General Meeting of the institute. 9 30 a m at Church House, Great Smith Street, Westminster, S W 1.
May Lecture by Prof A. G. Quarrell on ' Fifty years of metallurgical science,' followed by discussion. 3 p m at Hoare Memorial Hall.

APRIL 30
Two concurrent *Scientific Sessions*.

Programme 'A' (Hoare Memorial Hall): 'Age-hardening and related phenomena.' A discussion, based on published papers.

Programme 'B' (Convocation Hall): 'Refining of copper and copper alloys.' A discussion, based on the published papers.

Both to be held at 10 a m at Church House.

The afternoon will be devoted to discussions of other papers in two concurrent sessions at 2 30 p m at Church House. Chromium and nickel will be two of the subjects.

MAY 1
Four *Scientific Sessions*.

Programme 'A' (Hoare Memorial Hall): Symposium on 'Advances in inspection techniques as aids to process control in non-ferrous metals production,' arranged by the Metallurgical Engineering Committee. 9 30 a m.

Programme 'B' (Convocation Hall): Informal discussion on 'The life of fuel elements,' arranged by the Nuclear Energy Committee. 10 a m.

Programme 'A' (Hoare Memorial Hall): Symposium on 'Advances in inspection techniques as aids to process control in non-ferrous metals production' (continued). 2.30 p.m.

Programme 'B' (Convocation Hall): Symposium on 'Plutonium and techniques for handling it,' arranged by the Nuclear Energy Committee. 2 30 p m.

MAY 2
All-day Visits will be made by members to various works.

Calibration of hardness test blocks

A MACHINE has been built by the National Physical Laboratory to calibrate hardness test blocks and so provide a national standard of hardness. The machine is to provide a standard for the Vickers hardness scale, but the eventual goal of the research is to provide a standard also for the Rockwell scale.

The NPL machine uses a diamond pyramid which can be loaded with 30, 50, 100 or 120 kg correct to one part in 30,000 or better. The width of the indentation produced is then measured to better than 10 millionths of an inch using a microscope and a specially designed lighting system. From this, the diamond pyramid number can be calculated. The machine is accurate to $\pm$ 5 DPN units.

Initially, the load to be applied rests on a horizontal table with the diamond pyramid, rigidly attached to the load and pointing downwards, just clear of the specimen. The table is lowered hydraulically until the whole load is suspended on the specimen, the diamond pyramid acting as a single-point 'knife-edge.' The load thus hangs in free air and the force applied to the specimen by the diamond is due entirely to the load. By taking special precautions it has been ensured that the diamond pyramid remains vertical within 0·3 sec of arc. The hydraulic plunger which operates the table is of special design, as the table has to be lowered smoothly at a speed of 1/1,000 in/sec.

As there is no absolute standard of hardness, the accuracy of the machine can only be checked by measuring a specimen which is equally hard all over. Such specimens are extremely difficult to make and the NPL has had to develop new techniques to produce blocks of the required uniformity. The machine will be tested for long-term stability to ensure that its readings will not change from year to year. A difficulty here is that the only check on the machine is to measure from time to time the hardness of a standard block. It is known that steel, unless specially treated, varies in length as it grows older and it is likely that it also varies in hardness. To separate the possible variations of machine and test block, a number of blocks are being made of different steels and of similar steels differently hardened.

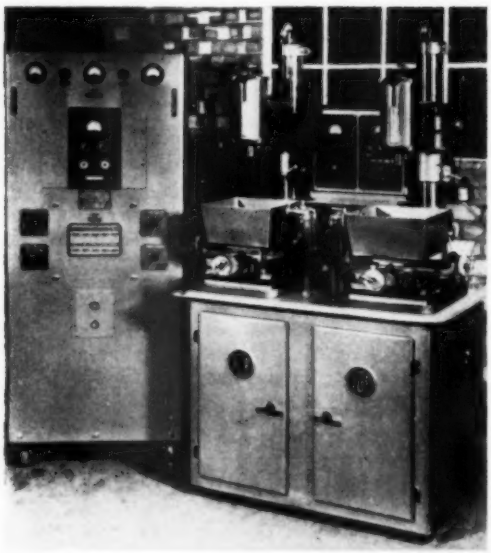
Open days at M E R L

The Mechanical Engineering Research Laboratory, East Kilbride, Glasgow, is to hold open days on June 4 and 5. Representatives of any organization with engineering interests will be welcome. Applications for invitations, stating which day is preferred, should be sent to the Director. The whole of M E R L will be open for inspection.

RIGHT *Examples of spark-machined dies*

BELOW *Double-head Sparcatron machine*

[*Photographs by courtesy of Burton Griffiths & Co Ltd*]



material of good electrical conductivity is suitable with, however, the apparent exception of aluminium and its alloys which form a non-conducting film of alumina on the surface.

At present, the alloy most widely utilised is first-quality brass because of its relatively low price and excellent conductivity. The first impression is made by ordinary methods of machining and with this one makes, before beginning production, a number of electrodes sufficient for the subsequent impressions. The small electrodes are made directly in the cold. The biggest are hot-forged and then cold finished to compensate for the shrinkage. Occasionally pure copper or copper-molybdenum is chosen or copper-tungsten which has a much higher resistance to wear but also a much higher price (around Fr.5,000/kg, equivalent to about 45*s*/lb). Bronze can also be used. Pure molybdenum gives excellent results and it is quite probable that special alloys found in industry in certain countries with different trade-names are to a large extent made up from it. With molybdenum the wear is one-fiftieth of what it is for copper and the only drawback of this metal is its price.

For establishing the first impression, a wooden pattern may be made and then a number of electrodes cast in brass or bronze in sand moulds. If it appears necessary to polish and finish the electrodes intended for the finishing stage, use may be made, either as-cast or lightly trimmed up, of those intended for roughing. The slight over-size allowance on the rough piece for accommodating the polishing is no handicap, for it will be worn away by the process of sparking well before reaching the depth at which there would be a risk of making too large an impression.

In the manufacture of fancy jewellery, a large number of dies are at present made by spark machining—particularly in England—by using as electrodes pieces stamped out in the former tools. In this application there is evidently no problem of dimensional accuracy.

The author has seen, again in Great Britain, tools

Stamping die mounted on a Sparcatron machine

the process was first applied by brass stampers. The requirements of steel stampers have caused manufacturers to consider more powerful models, or at least models capable of handling larger blocks. Thus Société Qualitex is at present engaged in designing a machine equipped with a 640 by 700 mm table (approx 25 by 27 in) and capable of working with an electrode of developed surface 12,000 mm^2 (about 20 sq in) at 150 mm^3 (about 0·01 cu in)/min.

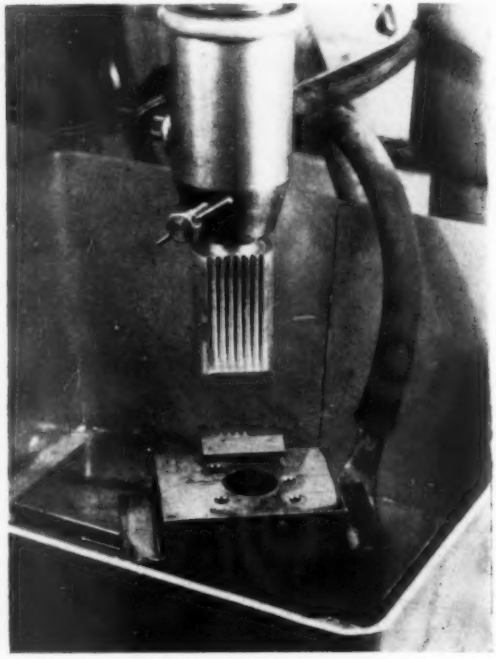
Acting along similar lines of reasoning, Languepin, which built some smaller models in the past, has now developed the Seleromat J5 machine which may be said to correspond to the needs of stampers. This model, with a 1,100 by 350-mm (43 by 13·8 in, approx) table, takes an electrode of developed area 20,000 mm^2 (about 31 sq in) and is capable of removing 500 mm^3 (about 0·03 cu in)/min when adjusted for roughing. The alternator which is included is driven by a 5-h p motor, but an 8kVA connection is necessary because of the pump motor, the servo-control of the head, the cooling fan and the indicating system. To cope with intensive work, the machine may be equipped with special filtering gear, operating, for example, by centrifuging. Finally, Languepin has now perfected a very simple device which permits the exact centring of the different electrodes employed for the cutting or repair of an impression.

The reader is asked to bear in mind the value of mounting a sparking head on the framework of machine tools which are no longer in service.

Electrodes

It may be stated that nowadays the making of an impression in a half-die generally requires two, three or four brass electrodes according to the volume of metal to be removed and the degree of precision which is required. Varying with the machine and the type of work, the loss of metal on the electrode amounts to between 25 and 50% of the volume cut away (in the case of brass electrodes) and as little as 1·5% for cupro-nickel electrodes. Researches currently under way will certainly make it possible to improve on these figures. It is frequently advantageous to use an extra electrode so as to gain greater precision in the impression and this electrode will still be serviceable for roughing out the next piece of work.

The alloy used for the electrode governs its method of production, its behaviour during operation and, naturally, its cost. In principle, any



Close-up of electrode mounted on Sparcatron equipment

Series on heat treatment

Distortion and cracking

F. D. WATERFALL

The large number of interrelated influences controlling distortion and cracking during heat treatment makes the subject a difficult one to present in an organized way. The author considers two main factors—change in shape and change in volume, and discusses ways of preventing the phenomenon. This lecture, the fourth of the lectures on 'Modern trends in the heat treatment of steel' given at the Wolverhampton and Staffordshire College of Technology, is concluded in this month's issue. The author is with the Technical Service Department, Heat Treatment Section, I C I Ltd., General Chemicals Division

concluded from last month

ANOTHER EXAMPLE of the effect of the mode of quenching on distortion lies in the quenching of ring dies. By quenching through the bore, the bore diameter is reduced in the quenching operation. The formation of martensite results in increased volume and contraction in the bore. If a ring die is quenched all over, the outside diameter increases and the bore will increase or decrease according to the precise dimensions of the part. If it is thin in comparison to wall thickness the hardening of the faces will cause an increase in thickness, a decrease in outside diameter and an increase in the bore. If the hole is so small that the quenching is not efficient, or if the hole is plugged, it will enlarge, due to the fact that it moves with the outside-hardened portion.

Effect of case depth and quenching temperature

Experiments on flanged En 32 steel rings as shown in Fig. 6 revealed that application of shallow cases around 0·005 in. at 900°C., followed by direct water quenching, caused the bore dimension 'A' to expand about 0·010 in. (Quenching similar rings from 900°C. in the absence of a case caused the bore to expand only half this amount.) When maintaining the quenching temperature constant at 900°C., but increasing the case depth, distortion became less until at 0·04 in. case the bore expansion was slight and at 0·06 in. depth of case the bore contracted. Less bore expansion occurs in the presence of shallow cases up to 0·025 in. by oil quenching from carburizing, followed by reheating to 780°C., and water quenching.

Martempering

Martempering is a means of reducing distortion occurring in hardening, particularly on parts of uneven cross-section which, if quenched in oil, would harden and expand at different times. Fig. 7 illustrates the rates of cooling obtained by quenching in water, oil, salt and air. During water or oil quenching the outside layers and thin sections of a component will pass through the M_s point and expand, whilst inside layers and thicker sections are still contracting prior to reaching the M_s point. These diversities cause stresses producing distortion (and cracking, to be mentioned later). If, now, the whole part is cooled to a uniform temperature prior to air cooling through the M_s point, then martensite formation takes place more or less at the same time throughout the piece and distortion is reduced. Martempering, unfortunately, is only applicable to small sections of water-hardening steel, but is suitable for most sizes of oil-hardening steels and all sections of air-hardening steels.

Fig. 8 indicates the reduction in distortion of 5-in.-dia. En 31 roller races by martempering in a molten salt bath, compared with oil quenching from a salt bath, or a conveyor's hearth muffle furnace. Fig. 9 shows the frequency of distortion on the same races. The type of furnace used for martempering these races automatically is shown in Fig. 10.

It is incorrect to assume that martempering is a cure for all movement in hardened parts; indeed, it is even possible to distort parts during martempering if the direction of salt flow is incorrect relative to the piece being quenched. For instance, in hardening the brake discs shown in Fig. 11, 17 in. dia

intended for brass stamping cut out by using hot-stamped pieces simply taken from the series made on the previous tool. It has been objected that the new impression must give poorer results than its predecessor by reason of the shrinkage which the pieces undergo after extraction from the die, but when the author put forward this argument, it was pointed out that this procedure is only adopted for work of small dimensions where the shrinkage is slight and where it would lie within the tolerances; further, the play between the electrode and the side of the die comes as a reduction of this difference. For long pieces, some users would cut and braze them to a larger block, thus correcting the difference due to shrinkage in the dimension where it is most significant.

Since the electrical conductivity of steel is not very favourable, one can scarcely use forged steel electrodes.

It is also feasible to make electrodes of wood, plastics or plaster without shrinkage allowance and then to coat them with copper afterwards. It is evidently necessary that the copper coating should be continuous and should join up with the metal shaft supporting the electrode and which carries the current. Because of the limited thickness of copper attainable on such electrodes, they have to be changed very frequently and are only suitable for light finishing work. It should be noted that there is a process of cold moulding with amalgam perfected by the Qualitex company. This has up to the present been applied only to small electrodes.

The dielectric bath

Mention has already been made of the function of the dielectric bath, *i.e.* to stifle the sparks and thereby prevent the formation of an arc and also ensure cooling and the carrying away of the detached particles.

The bath is generally a hydrocarbon. Petrol, fuel oil and mineral transformer oil are currently used. Other products have also been used, including paraffin oil.

In the earliest work on spark machining, the fluid was led in through the electrode-holding tube in such a manner as to ensure efficient exhausting of most of the residues. This procedure has the disadvantage of forming a 'core' inside the tube and which has to be afterwards removed; further, the electrode-holder head is complicated. For these reasons, numerous machine builders have abandoned it and have contented themselves with forming a current within the bath, compensating for the lower efficiency due to poorer exhaustion of the residues by increasing the electric power input. Other machine builders, on the contrary, have adhered to the principle of fluid flow through the electrode holder, which they regard as being essential.

The machines are provided with a motor-pump group giving high delivery under a pressure running to several tens of kilograms per square centimetre (equivalent to several hundreds of pounds per square inch). The fluid is always in motion and is subjected to continuous filtration.

On each machine there is a bath of sheet steel at the bottom of which the workpieces are placed. The bath is provided with an overflow pipe. The bottom may be formed of a magnetic platen intended to hold the blocks in place. The largest are held by means of clamps and bolts with special heads which are held in the ribs of the table.

Because of their weight and size, it is difficult to place large blocks on the bottom of a fixed bath. For this reason, Languepin is now developing a bath with movable side pieces.

Practical possibilities

Each spark attacks the piece to be machined by forming a small flat-bottomed crater. The surface of the impression thus formed is obtained by the juxtaposition of these multiple craters. These are increasingly small the lower the current. By controlling the current, it is possible to regulate the amount of metal removed and the surface quality. In practice, the work is divided into one or more roughing operations and a finishing operation. With the roughing conditions, the speed of cut and the volume removed are both relatively high and the surface condition is rather coarse. During the finishing operation, the rate of penetration and the volume of metal removed are small, whilst the surface obtained is of fine quality.

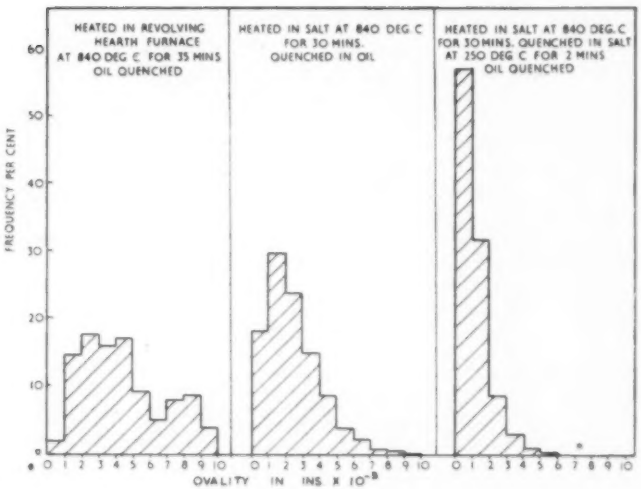
Thus the Languepin Seleromat machine can be operated at four different settings, to which correspond the figures in Table I for volume of metal removed, tolerances and surface quality.

TABLE I *Operation of Languepin Seleromat at four different settings*

Setting	Volume removed (mm^3/min)	Tolerances obtained (mm)	Surface finish obtained (μ)
Roughing (1)	500	± 0·1	10
,, (2)	75	± 0·05	5
Finishing	7·5	± 0·02	1·5
Super finishing	0·5	± 0·01	0·8

The precision realized depends evidently on the precision and the degree of wear of the electrode used in the finishing. It does not seem, however, that attaining the tolerances needed for stamping dies sets any problem.

continued on page 144

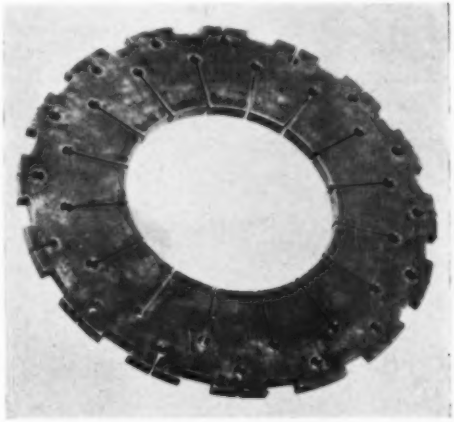

HEATED IN REVOLVING HEARTH FURNACE AT 840 DEG C FOR 35 MINS OIL QUENCHED
HEATED IN SALT AT 840 DEG C FOR 30 MINS. QUENCHED IN OIL
HEATED IN SALT AT 840 DEG C FOR 30 MINS. QUENCHED IN SALT AT 250 DEG C FOR 2 MINS OIL QUENCHED
FREQUENCY PER CENT
0 10 20 30 40 50 60
0 1 2 3 4 5 6 7 8 9 10
OVALITY IN INS. X 10⁻³

9 *Distribution of ovality resulting from various quenching methods for 5 in. o.d. rings (En 31)*

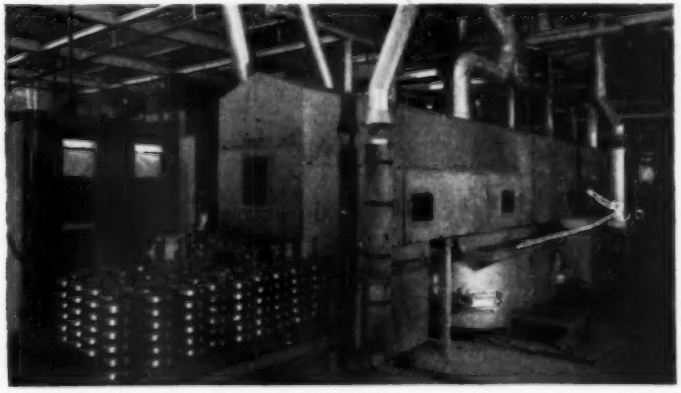
Fig. 12 indicates a method which facilitates case refining of some of the lower-alloy steels without having cooled these below the M_s point of either case or core until the final hardening quench. It is suitable to use steel with controlled grain size and cool from carburizing to 800° C., then harden by martempering. The temperature for the latter should be chosen in the light of steel analysis and the knowledge that M_s points for core and case differ. A compromise quenching bath temperature between the two is sometimes acceptable, provided that the soaking time in the quench bath is strictly limited to reduce isothermal transformation to a minimum. However, martempering in a salt bath held just above the M_s point of the carburized case and thus below the M_s point of the core has been shown to reduce distortion compared with straight oil quenching. The adoption of the cycle indicated in Fig. 12 reduced distortion on sliding dogs, 5½ in. o.d. by 4½ in. i.d. by 1 in. wide, in V 18A steel (En 36) to 1 to 2% outside limits, compared with 50% outside limits when gas carburized, followed by reheating in a muffle and oil quenching. Automobile gears are now being treated by this method.

Cracking during hardening

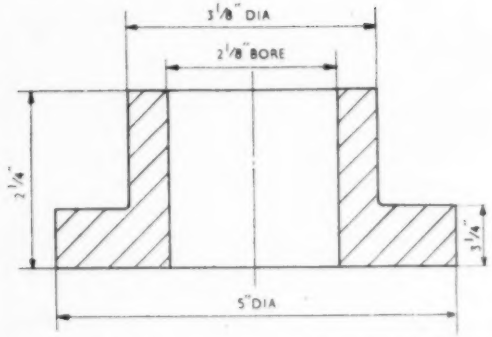
Instances of cracking during heating of large masses of steel, like ingots, due to too rapid heating, are known, but I have not had, in my experience, a confirmed example of cracking due to too rapid heating of smaller-sized pieces.



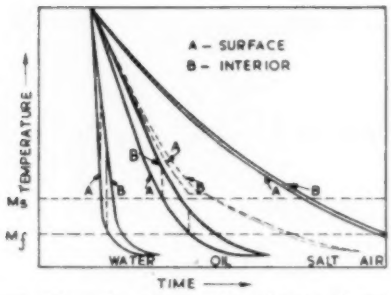
11 ABOVE 17-*in.-dia. brake discs which were found to distort beyond the required limits if the salt flow in the martempering bath was unevenly directed*



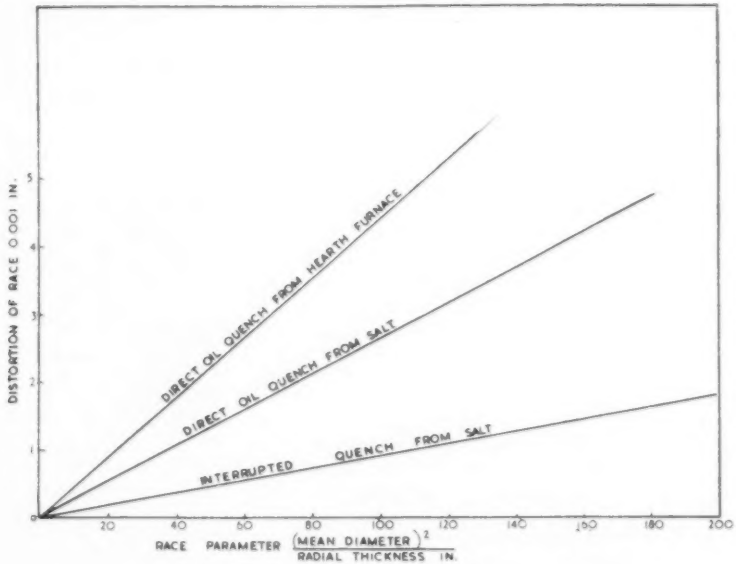
10 LEFT '*Cassel*' *CA automatic furnace used for martempering En* 31 *steel bearing races*



6 ABOVE *Ring used in experiments to determine the distortion occurring in components to which varying depths of case were applied*



7 ABOVE *Schematic representation of rates of cooling of a part cooled in either water, oil, a salt bath at 200° C., or air*


DISTORTION OF RACE 0·001 IN.
DIRECT OIL QUENCH FROM HEARTH FURNACE
DIRECT OIL QUENCH FROM SALT
INTERRUPTED QUENCH FROM SALT
RACE PARAMETER (MEAN DIAMETER)² / RADIAL THICKNESS IN.

8 RIGHT *The amounts of distortion obtained on 5-in.-dia. En 31 rings heated in (a) a muffle and oil quenched, (b) a salt bath and oil quenched, (c) a salt bath followed by martempering*

by 0·60 in. thick by 9 in. bore, in 1% chromium-molybdenum steel En 20, considerable trouble with distortion was met, even when martempering was employed. The trouble was eventually traced to an excessive agitation of the quenching salt and uneven flow of quenching salt (driven by propeller agitator) over the surface; 40% of discs were distorting more than 0·03 in. in the bore until modifications enabled movement to be reduced to 1 to 2% of discs with more than 0·03 in. bore distortion.

Again, carburized gears in 4½% nickel-chromium case-hardening steel En 39 (or equivalent) are notably difficult to harden without distortion, even by martempering, but best results in this respect were obtained by using a quenching bath held at a relative high temperature of 550° C., *i.e.* above the M_s point of both core and case, and then air cooling, although some loss in core strength results from this. This loss in core strength can, however, be overcome by oil quenching the parts after they have attained the temperature of the bath at 550° C. with, of course, some small increase in distortion.

Core and case of any case-hardening steel will transform to martensite at different temperatures—whether oil quenched or martempered—this tending to cause distortion, but the fewer the heating and cooling cycles the less will be distortion. It is preferable, if possible, to limit heating and cooling to one cycle so that, once a part has been heated up to the carburizing temperature, it should not be cooled to form martensite until the final quench to hardening, and this preferably by martempering. This is contrary to many of our conventional specifications calling for core and case refining of carburized parts.

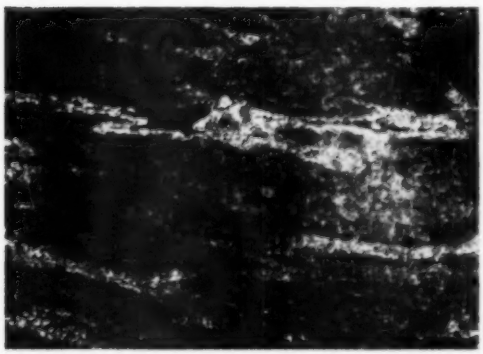
16 *A high-speed steel tool which cracked longitudinally due to a badly decarburized surface layer present on the original bar, which decarburization had not been removed by machining*

(calculated) M_s point of steel was reduced, or the carbon content increased up to eutectoid compositions, so the proneness to cracking during quenching increased. Fig. 13 summarizes their work. The deduction from this is that the lower the temperature of martensite formation in the steel, the more likely it is to crack, because at the lower temperatures there is less possibility of plastic flow to relieve stresses resulting from the expansion occurring during martensite formation. They say that quenching into salt at 150°C. is less severe than in oil, even when 100% martensite is formed in the salt quench.

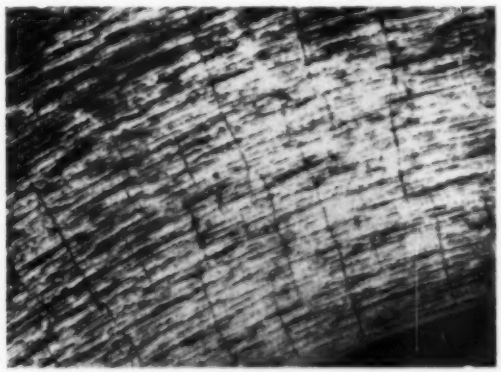
The well-known influence on cracking of stress concentrations at sharp corners of components has already been illustrated. Cracking of a part due to imposed notches in the form of lettering on a roll is seen in Fig. 14, and cracking of a case-hardened part through a roke in the bar in Fig. 15.

Stress relieving by tempering parts hardened particularly in water, but also in oil, will serve to prevent the stress cracking which may occur several hours after the part has cooled to normal temperatures. Stress relieving by secondary hardening hardened high-speed steel is of paramount importance in this respect. Two other common causes of cracking in high-speed steel tools during, or after, hardening are (i) non-removal of decarburization from the original bar stock and (ii) eutectic formation and residual untempered martensite in the vicinity of carbide stringers.

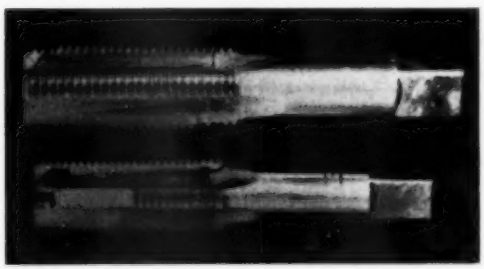
Fig. 16 shows a high-speed steel turning tool which cracked longitudinally some hours after hardening. Note the way the two halves have



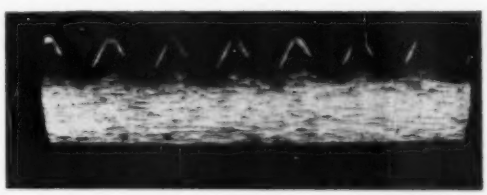
17 *A crack in a badly segregated zone in a high-speed steel cutter*



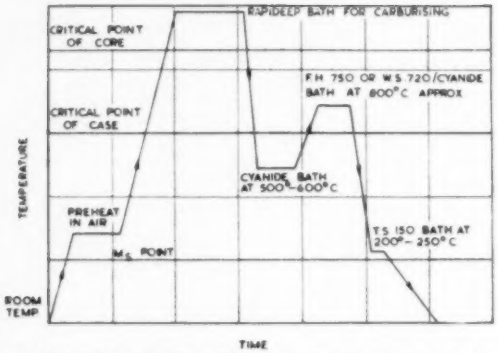
18 *Typical grinding cracks on the surface of a component overheated in grinding*



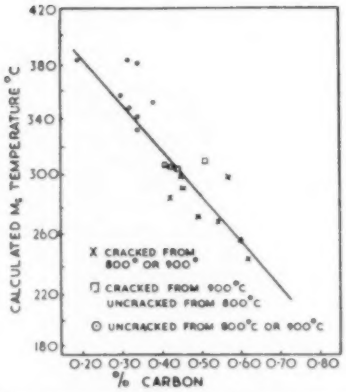
19 *A high-speed steel tap which cracked badly due to overheating when the thread was being formed by grinding*



20 *Microstructure of the tap shown revealed three distinct zones, (a) the material in the body, (b) a highly tempered structure, and (c) the overheated surface layers*



12 *Schematic representation of heating and cooling cycle for parts case hardened in salt baths, followed by martempering, the object being to avoid the part being cooled through the M_s point of case or core until final hardening is done by martempering*



13 *Relation between calculated M_s temperature carbon content of steel and proneness to cracking in alloy steels (Chapman and Jominy,* Metal Progress, *September,* 1953)

Cracking during quenching frequently results from the same factors which cause distortion, namely volume change. The deeper a steel hardens during a water quench, the more likely it is to crack during, or soon after, quenching. Again, the lower the M_s temperature in a steel, the more likely it is to crack during quenching. Too high a manganese content in a water-hardening carbon steel is a well-known cause of cracking. It is known to lower the M_s point in, and increases the hardenability of, the steel.

Chapman and Jominy did some work on engineering steels (*Metal Progress*, September, 1953) using a special crack test specimen, and found that, as the

14 ABOVE *A lettering roll which cracked in hardening through the imposed notches at the bases of the letters 'N,' 'Y' and 'R' which are roughly in line*

15 RIGHT *A case-hardened component which cracked through a roke present in .he original bar*

taken a curve, found to be due to a badly decarburized layer at the surface; this transformed on cooling at a higher temperature than the inner zone, which expanded when forming martensite at a lower temperature.

Carbide-rich segregates in high-speed steel are a known cause of crack development when the steel is hardened at its maximum hardening temperature, since this temperature is indeed excessive for the badly segregated zones, these being overheated with formation of eutectic carbides and a carbide-rich austenite/martensite matrix which is only slowly tempered during secondary hardening (Fig. 17).

Cracking during cooling from carburizing

A year or two ago considerable trouble was experienced during case hardening of nickel-chromium case-hardening steel En 320 (since removed from the 'En' range), due mostly to cracking in the case during cooling after pack carburizing. En 320 was similar to the German Specification 18 Cr, Ni 8, on which similar trouble has been experienced. It was found that rapid cooling from carburizing in oil, or air, eliminated cracking. Austrian work showed that a typical carburized case (0·80% C, 2% Ni, 2% Cr steel) transformed more quickly at 550 to 600°C. on slow cooling than did the uncarburized steel (0·20% C, 2% Ni, 2% Cr), so that the case which had transformed first was later subjected to stress when the core within expanded on forming bainite and martensite at a lower temperature. The resultant cracking is eliminated by cooling from carburizing sufficiently quickly to produce martensite/bainite in both case and core.

Cracking during grinding

This is mostly brought about by overheating of the surface layers of hardened parts, by generation of excessive heat, due to too deep a cut in grinding, use of an unsuitable or glazed wheel, or insufficient coolant. Grinding cracks on case-hardened work are generally, but not invariably, associated with surface softness, resulting from the heat generated, the cracks normally running on flat surfaces at right-angles to the direction of grinding as seen in Fig. 18.

A high-speed steel tap which cracked badly during grinding is shown in Fig. 19 in connection with which the microstructure, Fig. 20, shows three distinct zones: (*a*) The hardened and tempered structure, (*b*) an over-tempered soft zone and (*c*) a zone at the extreme surface in which the steel had actually been heated above the Ac point to reform austenite, which transformed to martensite on cooling.

Spark machining of forging dies

concluded from page 138

The length of the spark between the electrode and the workpiece is very small and very easily controlled; it may reach some hundredths of a millimetre on the roughing setting and will go down to one hundredth (about 0·0004 in) under finishing conditions.

Qualitex has adopted a special principle in the construction of its Usimu machines. These apply a pulsating direct current of constant value and operate at one single rate. The sparks produced are very small, very numerous and are all of equal size. A mean rate of metal removal of the order of 70 mm³ (about 0·004 cu in)/min and a very fine surface quality may be obtained. On this machine, the operator may touch the electrode without injury.

In die-sinking by sparking, the fibrous structure of the block is cut through as in milling, but clearly no tool marks can remain. Sharp angles come out well.

Since the sparks are short-lived and the circulation of the fluid ensures cooling, the material under treatment cannot lose its properties through becoming overheated.

Machining hard blocks

It must be put to the credit of spark machining that it brings with it the inestimable benefit of being able to handle the hardest blocks after heat treatment. The improvement of traditional chip-removing methods of machining has rendered possible the milling of blocks which are delivered at a hardness of 130 kg/mm² or even higher. Spark machining represents a further step forward and a decisive one, since it completely abolishes all consideration of the hardness of the materials undergoing machining. In particular, the problem of machining metallic carbides is shown to be solved. As well as making impressions in heat-treated blocks, the systematic maintenance of dies may be carried out without annealing by the use of the electric machine, the parting being put back to the straight. The replacement of hand finishing of dies after ordinary milling or in reproduction by an operation of spark machining may also be envisaged. Furthermore, blanking punches and dies may readily be executed.

When once set going, these machines can work unattended. In general, they incorporate a stopping device which comes into operation once a certain depth has been reached. One can thus leave these machines running unattended during the night and the new possibilities opened up for the stamping industry will readily be seen.

Radio-frequency induction heaters

R. P. P. ELLIS

The author, who is with George Wimpey & Co, evaluates the advantages of using radio-frequency heaters for thermal treatment of metals. In particular, he discusses factors which must be considered in choosing the generator and the problems involved in 'matching' to obtain maximum efficiency

THE SPECTACULAR GROWTH in the use of radio-frequency induction heating over the past 20 years, which has in many cases radically transformed conditions for the thermal treatment of metals, has now somewhat spent itself and a period of consolidation has set in.

Prior to 1940 the use of radio-frequency heaters was largely confined to the radio-valve industry for the out-gassing and gettering of radio-valve assemblies. Engineering applications of induction heaters principally employed motor alternators or spark-gap oscillators.

One of the main advantages of electronic heating for metals has been that it has brought heating for thermal treating and joining to a similar degree of precision as has been achieved in the machining and other shaping processes. The extravagance of some of the claims made for RF heating has been exposed, but it may fairly be stated that most of the difficulties are now solved by the RF-heater manufacturers, whereas in the past they were solved by the technical resources of those who have become their customers.

Advantages of the method

There are certain technical advantages of RF heating which are as follows: (1) The heating effect is confined to the surface of the work-piece; (2) the power density developed can be continuously varied from nothing to upwards of 100 kW/sq in; (3) to a large extent the pattern of heat generated may be controlled by the use of carefully designed inductors; (4) provided that dimensionally similar work-pieces are treated the heating effect is readily repeated. This assumes, not always validly, that the electricity supplies are constant; (5) the process may easily be controlled on a timed cycle and after setting up the operations may safely be performed by unskilled labour; (6) owing to the relatively high overall efficiency (up to 75%) the heaters cause a minimum of heating of their environment with attendant discomfort to nearby operators; and (7) in some cases the heating cycle is self-compensating.

In view of the high cost of RF power (at least £500 per kW of rated output for low-power generator sets), the operational advantages gained by its use must be overwhelming. They are of two categories: (*a*) the manner in which the heat is developed in the work and (*b*) the convenience with which it is so developed.

The power transferred to each element of the work is the product of the square of the current flowing through the element and its ohmic resistance (I^2R). The heating effect due to magnetic hysteresis is generally negligible. This is in no way contradicted by profound effects on heating response by materials, notably ferrous, which undergo a Curie change during the heating cycle. The contemplation of heating in relation to current and resistance is seldom rewarding as both vary widely, and to some extent unknowably, in practice.

The current distribution is not uniform. In the case of a round work-piece heated by a helical coil the current-carrying layer approximates to a shell of a thickness defined by the formula $\delta = 1{\cdot}98\sqrt{\rho/\mu f}$, where δ is the depth of the current-carrying layer, ρ is the resistivity, μ is the magnetic permeability and f is the frequency.

Table I, taken from 'Radio-frequency heating' by L. Hartshorn,[1] shows some values for typical methods. In point of fact, some current flows in all parts of the work and the heated zone is always many times the thickness of the current-carrying layer due to the effect of thermal conductivity.

Commercial RF-induction heaters operate at frequencies varying from 100 kc/s up to 20 Mc/s. As was stated earlier, depth of penetration is inversely proportional to the root of the frequency, thus the 200: 1 variation in frequency merely results in a 15: 1 variation in depth of penetration.

The main use of the skin-heating effect is for surface hardening when by the use of high-power densities (up to 20 kW/sq in) the surface layers of a direct hardening steel are austenitized while the core is untransformed. When a lower power density is employed, almost uniform heating can be obtained at a much greater heating rate than is possible with conventional muffle-type furnaces.

Generator output

The output characteristics of the generators have a great influence on the ease with which the power may be applied. The effects are summarized below where the only variable is the one stated, while the others remain constant: (1) For the same power with different frequency the coil current is related to the frequency as shown by the expression

$$A_1/A_2 = \sqrt[3]{f_2/f_1}$$

(2) The RF voltage across the work coil terminals is directly proportional to the frequency, thus

$$V_1/V_2 = f_1/f_2$$

where V_1 and V_2 are the work coil voltages of coils operating at frequencies f_1 and f_2 respectively.

(3) As stated previously, the skin depth is inversely proportional to the square root of the frequency, or

$$d_1/d_2 = \sqrt{f_2/f_1}$$

(4) For the same power frequency and coupling the work coil voltage is proportional to the number of turns, thus

$$V_1/V_2 = n_1/n_2$$

where V_1 and V_2 are the voltages associated with coils of n_1 and n_2 turns.

Generators are usually bought and sold on a basis of rated power output into a water-cooled steel load. Although this is a reasonable compromise of interest between vendor and buyer, the detailed specification of the generator is of great importance. Coming a close second to the rated power is the ability of the set to be tuned to deliver as high a proportion of power as possible into a wide variety of loads; this is because it is seldom economically possible to design and supply a generator for one application only.

The work-coil voltage in any application has an important effect. If the voltage is too high the reliability of the set-up is gravely impaired. In practice, the work-pieces are seldom either clean or dry. Once an arc has been struck between coil and work *via* a bridge of sludge there are sufficient volts to produce a 'flash-over.' As the power factor of the loaded work coil lies somewhere in the range of 0·0005—0·010 there is ample kVA available to sustain the arc and usually some material damage occurs at least to the inductor before the overload trips in the generator have time to act. At all events, 'flash-overs,' being high-current arcs, cause alarm and despondency in even the most phlegmatic operators and any by-standers. The actual physical danger is not great, as RF current is of too high frequency to cause electric shock. The main hazard lies in surgical shock occasioned by burns.

To keep the risk of 'flash-over' to a minimum, it is necessary to keep the voltage as low as possible. In many cases one of the output terminals is earthed, which as the work is usually itself earthed, keeps the work coil/work voltage at a low level. (The minimum theoretical voltage occurs when the coil is centre tapped to the work.)

Importance of 'matching'

The impedance which the combination of coil and work present to the set must be matched to the designed output characteristics. To obtain maximum throughput, it is necessary to draw the maximum designed output power from the generator at all stages of the heating cycle. This can seldom be achieved as the resistance, permeability and to a small extent the dimensions change by virtue of the act of heating.

The major cause of 'mismatch' is due to the Curie change in heating steel through its critical range. If a generator is set to deliver its maximum power into a magnetic-steel load, the load on the set when the steel has passed the Curie changepoint is reduced to about a quarter. When it is desired to through-heat the steel to a maximum temperature of about the Curie point, this can be advantageous, *e g* for silver brazing or sub-critical annealing. The reason for the reduced power in the work can be seen in Table I if the depth of current penetration is compared above and below Curie. (The increased depth above Curie causes a lower resistance to be reflected into the tank circuit of the oscillator.) If it is desired to realize a more substantial proportion of the rated power of a set into a load which changes its permeability as steel does, it is quite practicable to re-match during the heating cycle. If the work-coil is transformer driven from the tank circuit of the oscillator there is sometimes provision for altering the coupling of the transformer. Alternatively, the work coil can be partially tuned by a condenser after the Curie point has been passed. Both of these re-matchings can be made without switching off the generator.

An interesting effect of frequency is on the

TABLE I *Depth of current penetration for typical metals*[1]

Metal	Resistivity, $\mu\Omega$-cm	Permeability, μ	Depth of current penetration δ in inches		
			10 kc/s	100 kc/s	1 Mc/s
Copper ..	1·7	1	0·026	0·008	0·003
Brass ..	7	1	0·052	0·017	0·005
Steel, hot:					
Above 780°C	120	1	0·216	0·069	0·022
Below 780°C	40	40	0·020	0·006	0·002
Graphite ..	800	1	0·600	0·170	0·060
Tap water ..	2,000	1	0·870	0·280	0·087

degree of mismatch caused by the Curie change-point. This mismatch is due to the change in permeability from about 100 to unity. The actual figure for permeability is itself frequency-dependent for the permeability is defined by the formula $\mu = 1{\cdot}8B/H$, where μ is the permeability, H is the magnetizing force and B is the flux density. As was shown earlier, the work coil current is frequency-dependent, thus the flux density is as well. A line of enquiry which leads from this is the effect of heavy low-frequency or even d c currents superimposed on the RF power current in the coil on the Curie mismatch.

The most important effect of frequency is on the voltage. As well as the effect on the tendency to 'flash-over' there is its effect on the degree of coupling which is practicable.

An important consideration is that of the impedance of the output. Similar heating effects are achieved with the same power and frequency, but different combinations of work coil current and voltage, but if the current is low the voltage must be high. In general, it is less expensive to manufacture a low-current generator and it is unfortunate that this is the less desirable type of set.

The heating effect is governed by the ampere turns of the coil, thus a multi-turn coil of low current can have the same power as a single-turn coil of higher current. For cylindrical coils the number of turns cannot be lower than unity and, where the ratio of length/diameter is much more than about three-quarters, a multi-turn coil is necessary. It is, of course, sometimes possible to scan the surface to be heated by passing it continuously.

TABLE II *Frequency and power relationship of generators*

Generator	Power in kW	Frequency, kc/s	Remarks
IH 38	1·25	1·0—1·3 × 10^3	Coil current 85 amp max Work coil voltage 450 rms max Power input 3·8 kW
IH 42	3·0	1 × 10^3	Coil current 130 amp max Work coil voltage 450 rms max Power input 4·8 kW
IH 42B	3·0	400—650	Special generator for loads of high Q and inductance
IH 39	9	475	L 1·5 H Q loaded 16 Q unloaded 80 Power input 15 kW
IH 43	21		L 2·04 H Q loaded 16 Q unloaded 79 Power input 40 kW
IH 41	31	475	L (loaded) 2·04 Q loaded 16 Q unloaded 79 Power input 67·5 kW
IH 45	125	225	Power input 220 kW

The reduction in heating rate above the Curie point during skin hardening is not wholly detrimental, for it acts in some way as a safety valve and as an automatic compensation for electricity and dimensional changes. Frequently it has been found that a striated heat pattern develops just as the work is passing through the Curie point. This is thought to be due to channelling of the current through that part which has passed through the magnetic change and consequently presents a reduced resistance to the RF current.

Where it is essential to obtain the maximum output from a given size of set, it can sometimes be arranged to draw a nominal overload into the work below Curie and to compensate for this by underloading afterwards. More importance must be attached to this when heating for forging, but generally rotary converters are more suitable for such applications.

One of the main advantages of RF-induction heating which has not been fully emphasized is the latitude in temperature which can be tolerated when the overall heating does not exceed a few seconds. Provided that incipient fusion does not occur, neither grain coarsening nor scaling sets an upper limit to the temperature that can be used.

RF heating of non-ferrous metals is, in general, difficult and special advantages must be present for it to be economically sound. Owing to the poorer response by non-magnetic metals the voltage tends to be excessive.

The foregoing discussion indicates some of the desirable features for induction heaters and it is interesting to list the products of one of the leading British manufacturers (Table II).

It will be seen how the frequency is reduced as the power is increased. The remarks are taken from the data published. Q is a term which is defined as the reciprocal of the power factor. A coil and work combination which has a Q of 16 has a power factor of 0·0625 and it may be assumed that, where a Q of 16 is quoted, the set can be fully loaded into such a coil. A better idea of the adaptability of the set would be gained if the maximum voltage, current and kVA available were also quoted.

The claim has sometimes been made that the generator supplier is uniquely qualified to design the handling gear, but until RF heaters are suf-

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National Association of Drop Forgers and Stampers

annual general meeting

THE ANNUAL GENERAL MEETING of the National Association of Drop Forgers and Stampers was held at the Botanical Gardens, Edgbaston, Birmingham, on Tuesday, February 25, 1958, with Mr. R. Bennett (president of the Association) in the chair.

Owing to the very inclement weather—a heavy snowstorm had raged throughout the country during the previous night—it was impossible for a number of members, from Scotland and Yorkshire in particular, to attend the meeting; nevertheless, there was an attendance of 90 members and associate members, and the gathering was remarkably representative.

Amongst the absentees was Col. J. W. Danielsen, D.S.O., D.L., J.P., a past president of the Association; Mr. Bennett made mention that Col. Danielsen had just retired from the chairmanship of the Deritend Stamping Co. Ltd., of which he had been a member for 56 years. The president paid tribute to Col. Danielsen's work for the Association and for the Deritend Stamping Co. Ltd., and pointed out that this was one of the very few occasions over the last 40 years when Col. Danielsen had not attended an annual general meeting.

It is the normal procedure of the National Association of Drop Forgers and Stampers that their presidents hold office for a period not exceeding two years, and Mr. Bennett pointed out that his term of office was now terminating; following on the formal proceedings, Mr. Bennett proceeded to install his successor Mr. J. H. Swain, managing director of the Stampings Alliance Ltd., as president of the Association for 1958. He referred to Mr. Swain's long service to the Association as a member of many committees, and in particular vice-chairman and in due course chairman of the Commercial Committee. He felt that there could be no one more worthy of the honour of being president of the Association than Mr. Swain.

In a short presidential address, Mr. Swain commented on the appointment of Mr. G. Jackson as technical officer, and felt that members might be assured that the question of technical efficiency and research would be kept very much under review. After referring to the work of the Commercial and Labour and Welfare Committees, Mr. Swain went on to deal with the question of the European common market. He could see the possibilities of increasing the export trade in certain types of drop forgings but felt that in other directions the industry would be faced with keen competition at home; as an example he mentioned hand tools. He pointed out that the major effect would be the consequence that the free trade area would have on the industry's chief customer, the automobile industry. He was told that here it was hoped that the new structure would increase our export trade to Europe. He felt that the bonds of friendship which the Association had already established through its Associate Members' Branch with overseas drop forgers would be most helpful under the new economic structure envisaged.

Mr. Swain then presented Mr. Bennett with a handsome silver salver, the gift of members of the Governing Council of the Association, as a token of their regard and esteem.

President's Report

In his annual report of the work of the Governing Council of the Association during 1957 Mr. Bennett said that the Association now had 78 full members as against 79 reported last year.

The Associate Membership Branch had increased from 40 to 43 by the addition of one Australian, one French and one Spanish firm, and members would be interested to know that their friends in Australia had now formed their own Drop Forging Association. This had been under consideration for some time, but came to fruition in 1957.

The elections had brought forward a number of changes in the composition of the Governing Council. Mr. D. B. Russell, of Thos. Smith, of Saltley, took the place vacated by Mr. Swain on Group 'C.' Mr. T. G. Barford, of Halladays Drop Forgings Ltd., had been elected to Group 'D' and Mr. R. Nightingale, of Light Metal Forgings, to Group 'F.'

The 1958 budget called for an increased annual subscription from members. This was partly due to the general inflationary tendency, but in great measure to the increasing scope of the Association's activities. He felt that the increase was fully

justified and was sure nobody was going to grudge this contribution towards progress.

Mr. Bennett said he would leave the details of committee work to the chairmen of committees to report, but he would mention that during the last six months the new ' Safety Booklet,' for which the demand at the moment was towards 10,000 copies, had been published. This was the work of a joint committee of the Publications and Labour and Welfare Committees, and thanks were due to Mr. G. H. Fisher of the English Steel Corporation for the admirable manner in which the document has been produced. The Publications Committee and the Labour and Welfare Committee had also been responsible for some valuable recommendations on fire precautions in the drop forge. The Technical Committee had published the Hammer Foundations report and the Commercial Committee has published the standard terms and conditions of sale of the Association. A revised ' Standard Extras ' list would be published quite shortly.

The general trend of business during 1957 had been patchy. The cut in the nation's defence expenditure had brought unwelcome developments to the members who were concerned in light alloy and blade forgings. The recession in the motor trade caught the drop-forging industry in its toils in the early months, but there had since been a remarkable recovery, and in many quarters members have been hard put to it in meeting the advancing schedules. He thought that they should take this opportunity of congratulating the motor industry on the wonderful part which it plays in the export trade and for its exceptional resilience. There had been a substantial demand for drop forgings from the general engineering industry, with exceptional high spots in the colliery and railway sections.

Yet, whilst on many hands member firms were extremely busy, there were reports of those who were not so fortunate. Indeed, it was clear that this must be so, if only by reference to the astonishing prices which had been quoted.

The future, however, looked reasonably encouraging. The S.M.M.T. had revealed their building programme on an increasing scale up to 1962. The N.C.B. and the railways reported their demands for forgings in 1958 and 1959 would follow very much the current pattern. There was no evidence that the general engineering industry would be reducing its demands. Easement in the bank rate would lighten the picture all round, and all might surely hope that this would not be long delayed.

Mr. Bennett said he had now reached the end of his presidential period of office. He laid down the duty with grateful acknowledgment of members' kindness, tolerance and understanding. The cares of the office were a considerable addition to the normal duties of any business executive, but he could say without hesitation that no one could have been better served than he had by the courteous and competent headquarters administration under the control of their efficient director, Mr. A. L. Stuart Todd. Their willing co-operation has been a tower of strength during the whole period.

Mr. H. G. Bown, director, Firth-Derihon Ltd., moved the adoption of the report in an eloquent speech, and Mr. F. J. Hickman, director, Drop Stampings Ltd., seconded.

Mr. P. Wyld, director of Harry W. Wyld & Co. Ltd., chairman of the Finance Committee of the Association, presented the accounts for the year 1957, which were agreed.

Report of Technical Committee

Interesting reports of committee work were presented by the chairmen of the respective committees. Mr. H. Perry, director of Smith's of Coventry Ltd., chairman of the Technical Committee, said that it had not been easy to fill the position of technical officer, but they had been fortunate in securing the services of Mr. George Jackson who joined in July last. Many members had by now had the opportunity to meet Mr. Jackson and the committee were happy to record that their activities had been stimulated considerably now he had settled down to his task to which he brought much experience and great enthusiasm.

It was natural, said Mr. Perry, that during the last few months when Mr. Jackson had been getting to know the industry there should be a period of review and revision of the technical activities of the Association. He would take this opportunity of recommending the use of the Association and the technical officer for any queries and problems.

Meanwhile, the routine work of the committee continued. There had been four meetings of the main Technical Committee, for which a regular programme of at least six firm dates per year was now established and there had also been a number of meetings of the various sub-committees, some of which are being reconstituted. A new sub-committee to deal particularly with technical publications was being set up as a result of a recent recommendation made to the Governing Council by the Publicity Committee.

The 1957 series of spring lectures was held as usual and again six evenings were arranged. Attendances were good and the total number of tickets sold was 267. A further series had been arranged for this spring and would begin on Tuesday, April 22, but this year in the Birmingham College of Technology at Gosta Green, where considerably better facilities existed than in the Mason Theatre.

The Technical Convention was held in November

Flame hardening

G. MEREDITH, B Sc

The advantages of flame hardening for certain applications are discussed in relation to the principles of the method. Equipment required both for general work and for special applications is described, and the points to be observed in handling different ferrous materials are detailed

CORRECT HEAT TREATMENT is becoming increasingly important in the preparation of the steels and cast irons used in modern structures and machines. Of all the heat-treating processes, flame hardening generally requires the least expensive equipment, and offers the greatest flexibility and speed. Equally adaptable to massive parts and to tiny mass-produced components, the process has earned an established place amongst modern production methods and provides industry with an efficient and economical way of hardening a surface effectively without, in most cases, affecting the strength of the core of the metal.

The advantages of flame hardening are more easily understood when we keep in mind the elementary facts about the moving parts of machinery. The majority of failures in machinery occur in moving parts and predominantly stem from wear. If we examine the effects of wear on such parts we find that the contact surfaces which wear and break down comprise only a small fraction of the total mass of the part and, indeed, often only a portion of its total surface area. In addition to surface abrasion, these parts are subject to other demands. They have to bear torsion, compression, tension, bending, impact and vibration leading to fatigue and in many cases corrosive actions as well.

The real criterion for a component is its ability to meet its service requirements. The ultimate for one part will be toughness and ductility, to meet flexing loads; for another it will be hardness sufficient to cater for sliding abrasion; for a third it will be tensile strength. For most mechanical parts this is further complicated by the necessity for a combination of two or more properties in different sections of their mass. Gear teeth, for example, need a hard-wearing surface on a tough core and gear body to take operational loads.

It would be possible, no doubt, to make each part of a special material with properties matched to the specific requirements of that particular unit. A group of such components would constitute an assembly with good all-round service life. Unfortunately, this would be uneconomical and we must instead adopt special handling of more general-purpose materials to give a good degree of special properties in the part. Steel is a basic engineering material and, with proper handling, comparatively few basic analyses of steel can provide most of the working properties we demand. And so in the case of the gear, as in many others, we rely on the character of the steel to give the desired quality in the core and we need only provide a surface hardness to make the part satisfactory.

1 *Typical vertical shaft-hardening set-up at Flame Hardeners Ltd, Sheffield. A ring burner and vertical traverse are incorporated*

Fundamentally, then, we must guard against two separate causes of failure. One is the fracture of

at Droitwich as usual. This well-attended event was one of the most popular in the year. Visits arranged for members last year were to the A.I.D. laboratories at Harefield in May, a large party of over 60 members went to the British Railways works at Derby in October, and some 40 members attended the Spark machining exhibition in Birmingham.

The technical bulletin had been published regularly, four issues and one special issue appearing during the year. A new feature was the inclusion of special news items of technical interest.

In conclusion he would like to express the committee's appreciation of the efforts of the director and Miss Wilkinson, particularly during the period when we were without a technical officer, and also express personal thanks to the members of the Technical Committee.

Report of Commercial Committee

In the absence of Mr. S. Johnson, director of Daniel Doncaster & Sons Ltd., the vice-chairman of the Commercial Committee, who was unable to attend owing to bad weather conditions, the director of the Association (Mr. A. L. Stuart Todd) read the report of commercial activities during 1957. Some of the points made in the report were as follows:

'As in past years, the main work of the committee can roughly be divided under two headings. Firstly, negotiations with the British Iron and Steel Federation to assure supplies of steel to the industry and, secondly, the consideration of the effects of increased costs upon our sale prices. A word first about drop-forging output in 1957. The net result of our trading last year can perhaps best be shown from the statistics of our net weight deliveries of drop forgings which are returned to us by our member firms. These show that in 1957 we delivered 313,897 tons of steel drop forgings as against 318,979 tons in 1956. You will note that the figures for 1956 and 1957 almost balance. I should, however, point out that in recent years Mr. Swain has nearly always been able to report a substantial upward trend in deliveries as the years have gone by and, indeed, with the very much greater capacity and efficiency of the industry, such an increase has obviously been necessary to our economy.

'Much of our time has been taken up in the consideration of steel supplies. At the beginning of the year shortages were reported in alloy steels and also in carbon billets, which represent one-third of our total usage. The overall steel position has improved during the year and we are advised by the British Iron and Steel Federation that the alloy steel position is likely to improve progressively. The general carbon-steel position is very much easier, but we are still apprehensive as to supplies of forging billets. Here we have been looking to the future as, by the end of 1959, we expect that a certain supplier on whom we greatly rely will no longer be able to help us. We have actually been advised by the British Iron and Steel Federation of alternate sources of supply and, indeed, we have circulated lists of steel-makers who, the Federation tell us, should be able to help us in the future.

'The Commercial Committee looks ahead and is continually planning for the future. We have been greatly assisted in this matter by figures of automobile production supplied to us by the S.M.M.T. We have also been assisted by our own member firms who have given us details of their likely requirements in the future. We are thus now able to present a picture to the Iron and Steel Board as to the supplies of steel we shall probably be needing, in any case in the near future.

'The sale prices of our products have been affected by the inflationary period through which we have been passing, although there has been an interim period in the last six months during which things have been comparatively static. Our prices have also been affected by the increase in the wages in the engineering industry which became operative in April. We were able to give our members details of the price determinations of the Iron and Steel Board (so far as they applied to our industry) almost immediately after the publication, and we believe that this service is much appreciated.

'The Standard Terms and Conditions of Sale were revised during 1957 and have been circulated to members.

'Members have been advised against entering into fixed-price contracts except in special circumstances, and information on the subject of the relaxation of import duties on steel, export conditions, steel scrap prices and the like has been given. Close touch has been kept with the requirements of the Restrictive Trade Practices Act and the position of member firms in this respect.'

Mr. W. E. Golcher (chairman of the Publications Committee) reported on a scheme of reorganization of the work of his committee which had recently received endorsement in principle by the Governing Council. The director (in the absence of Mr. M. C. Vaughan, chairman) reported on the work of the Labour and Welfare Committee which had had a particularly busy year.

When the proceedings of the 39th annual general meeting of the National Association of Drop Forgers and Stampers had finished, lunch was taken by those present.

2 *A ship's gudgeon pin being flame hardened by the progressive method. The cooling jets are situated behind the flame area*

suitable and a burner can be made to suit the physical shape of the component.

Equipment

Equipment for applying the process may be very simple or very elaborate. For mass production, use is made of what amounts to a flame-hardening machine tool specially designed for the job in hand. For more general work, standard parts are combined to provide a set-up which is both simple and adaptable. A portable cutting machine carrying the burner and quench will cope with the greater proportion of straight line work. A lathe and a fixed burner will handle most circular work and a variety of simple fixtures will accommodate more complex operations.

The width of the burner and quench spray should correspond to the width of the workpiece, and the tip of the flame should be just clear of the surface. If only a relatively small area of an article is to be subjected to treatment, access for the burner may be difficult owing to projections, bosses, flanges and so on. Therefore, each flame-hardening job must be treated as an individual case, it being almost necessary to design and manufacture a particular burner to suit it. On the other hand, repetition work such as occurs in gear, worm and sprocket hardening permits the employment of burners capable of a wide range of adjustment for size, and to which one or more nozzles may be fitted as required.

The factors controlling the choice of fuel gases for flame hardening are economy and efficiency. While oxy-coal gas and oxy-propane have been used for certain applications, it has been found that the oxy-acetylene flame offers many advantages, *e.g.* ideal heat-transfer properties and easy control and setting of flame conditions. A neutral flame is most commonly used. This is a flame consuming equal proportions of acetylene and oxygen, and it is easily recognized by its clearly defined inner cone and generous orange-red secondary flame. Occasionally an oxidizing flame is used. This flame gives a higher heat input than a neutral flame and, due to its considerably reduced secondary flame, less heat is lost to the atmosphere.

Applications of flame hardening

For hardening cylindrical surfaces, the progressive technique is the preferred method, and is used wherever it is possible to rotate the part. With it, maximum uniformity and freedom from soft spots is obtained, with correspondingly improved service life. A ship's piston groove may be flame hardened by the progressive method, the piston being rotated carrying each groove in turn past a stationary burner and quench. The only alternative to flame hardening in this example would be the welding-in

3 *Flame hardening starter rings by the consecutive method at Francis B. Willmott Ltd, Birmingham*

the body of the part through fatigue, poor design, lack of material strength or residual stresses. The other is the wearing due to contact of bearing surfaces. With the demand for more compact equipment of greater load capacity, the need to prepare these contact surfaces with precision and speed has grown in importance.

The job can be done by any of the following methods: Full-quench heat treatment; localized case hardening; chapmanizing; nitriding; induction hardening; chrome plating; metallizing; hard facing or flame hardening. With the exceptions of flame hardening and hard facing all these processes require considerable operating time and space and bulky and expensive equipment. For economy, precision, flexibility and speed, no process can handle the variety of work with the success that flame hardening can.

The flame-hardening process itself is not new, having been patented for gear hardening as early as 1910. The method, at that time, was to mount the gear in a tank partly filled with water so that each successive tooth could be heated with a hand blowpipe and then quenched by rotating the gear. But neither the depth nor the degree of hardness could be controlled by this rather ' hit and miss ' method. In 1925, A. E. Shorter rationalized the technique by passing an oxy-acetylene flame across the surface to be hardened, followed closely by a quenching spray, both flame and spray travelling at a constant speed and keeping at a constant distance from the surface. This improvement made it possible to achieve maximum hardness on the surface layer without changing the core condition of the metal. Today this technique is in common use and various adaptations have enabled the process to be applied to a wide range of components.

Flame-hardening practice

For flame hardening to be successful, the superficial layer of the article to be treated must be brought to the correct temperature and quenched before the heat can penetrate into the body of the workpiece. More heat must be absorbed into this layer than can flow away into the core. Thus flames of high temperature and large heat concentration must be employed to create a superficial damming up of heat. It is essential that the heat output of the hardening flame be correctly chosen; if it is too great, the surface of the workpiece will be melted; if it is too small, it will not be sufficient to obtain a given depth of hardness.

Flame hardening is advantageous because the depth of hardness can be strictly controlled and only the sections requiring treatment are selectively hardened. It is ideal where hard-wearing surfaces are required on a tough and ductile body.

Most steels or irons which are hardenable by furnace processes can be hardened by the flame-hardening process. Straight-carbon steels are the most commonly used; next medium-alloy steels, and finally high-alloy steels. In all cases the depth of hardness is closely controlled and is generally in the region of 0·1 in.

The four following methods of application are available to industry, the choice being governed by the nature of the component to be treated: (1) Work remains stationary, and the gas burners and quench jets move in relation to it.

(2) Burner and jets remain stationary while the work travels past them.

(3) Burner and jets move horizontally or vertically while the work revolves.

(4) The revolving work is heated by a stationary burner which is then removed or extinguished and the quenching spray applied.

The first three methods are known as progressive hardening, and the fourth is termed consecutive hardening. In the progressive systems, the heating and quenching operations are combined, the quenching spray following behind the burner, moving in the same direction at the same speed. The rate of heating is regulated by burner size and speed of travel. The effectiveness of quenching is regulated by the volume of water passing per unit time and by the distance between the jets and the burner. In the consecutive method, heating and quenching are separate operations. The heating rate is controlled by the burner size, and the intensity of quenching by the time which elapses between extinguishing the burner and bringing the quench into operation. The burner and quenching spray usually move over the surface to be hardened at a speed of 3—12 in/min, depending on the thickness of the article to be hardened and the depth of hardness required.

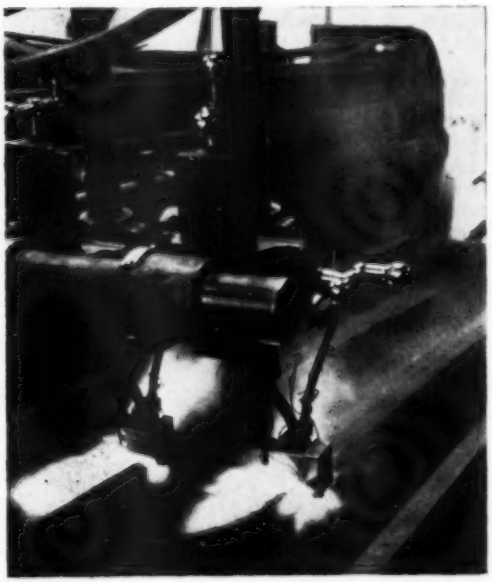
According to the design and analysis of the part to be hardened, so the quenching rate is determined. In the case of shapes and materials that are able to withstand drastic or full quenching, a water quench $\frac{3}{8}$ in behind the heating is applied, the water pressure being in the order of 30—40 lb/sq in. As the shape or material of parts enforces the use of less and less drastic quenching, either an aqueous solution, compressed air, or even still air may be used. It is important that parts are never fully quenched; a temperature of about 250°C should always be left in parts treated and, where possible, a stress-relieving treatment should follow.

Originally, flame hardening was employed almost exclusively for gear teeth. However, the technique has been improved and developed so that flame hardening of many other components is now standard practice. Any component can be flame hardened provided the steel is metallurgically

four 20-jet water-cooled burners spaced around it. The whole tooth area of the gear was heated just above the 'upper critical temperature' and then plunged, still spinning, into the quench. Total time taken to harden this gear was 2½ min and an average hardness reading of 61 Rockwell C was obtained. In addition to normal hardness tests a more severe test was conducted. The gear was mounted with one ½-in shear bolt on a machine which was then set in motion and jammed. This should fracture either the shear bolt or the teeth of the gear, but in each test it was the bolt which fractured whilst the flame-hardened gear showed no sign of wear or breakage.

For large gears the progressive method is employed. The gear is kept stationary whilst each tooth is being treated. Special burners and quench jets are applied to both contact surfaces of the tooth simultaneously as illustrated diagrammatically in Fig 4. This method is also applied to sprockets. The burners and quench jets may be mounted on a motorized tractor to give a controlled rate of traverse.

The flexibility of the flame-hardening process is illustrated very clearly in its adoption by a company manufacturing cash registers and accounting machines each of which contains many minute components. Most of these parts are subjected to considerable stress and wear and, although the parts are small, it has been found possible to apply the process successfully. An example may be given of the set-up for the production hardening of rack teeth. These racks are $\frac{1}{16}$ in thick and the teeth of $\frac{3}{16}$ in pitch require a hardness depth of $\frac{3}{32}$ in. The rack is supported in a tank of water and soluble oil with the top of the teeth just showing above the liquid. The oxy-acetylene flame is applied in the form of two jets converging at the root of the teeth. The burners are mounted on a tractor and driven at about 150 ft/h which is probably the highest known flame-hardening speed. The output of hardened racks is about 1,400/week.



6 *Flame hardening a lathe bed. The burners are shaped to fit the contours*

Plain carbon steels

For flame hardening, fine-grain steels are preferred exhibiting resistance to grain growth in the austenitic region, with shallow hardening tendencies. From this the main consideration is the carbon content. For standard production, plain carbon steels containing from 0·35—0·83% C can be hardened, special attention being required for hyper-eutectoid steels. The correct heat input and distance between flame and quenching spray must at all times be strictly maintained to give the optimum result. The most commonly used steel for this process is 0·40% C (BS 970: 1955, En 8).

Cast steels

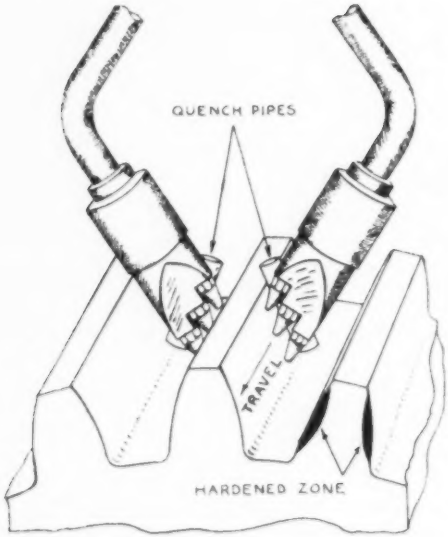
In the case of cast steels, it is always desirable, from the flame-hardening point of view, to remove the surface casting skin. This is normally found to be decarburized. If, however, the part to be treated cannot be machined, it is always best to increase the carbon content of the casting by about ten points to compensate for this skin. If this is done, then a hardness of up to 500 Brinell can be anticipated. The surface of unmachined castings must always be cleaned of rust, foundry sand, and other impurities, as these would interfere with heat transfer and quenching, causing soft spots in the hard surface.

In the case of castings, a high-tensile core is often demanded; this can be obtained by preliminary heat treatment of the mass to the machining range of up to 350 Brinell and, after machining, flame hardening is applied to the surface. This gives a most satisfactory combination of physical characteristics which can be obtained only by this practice.

Alloy steels

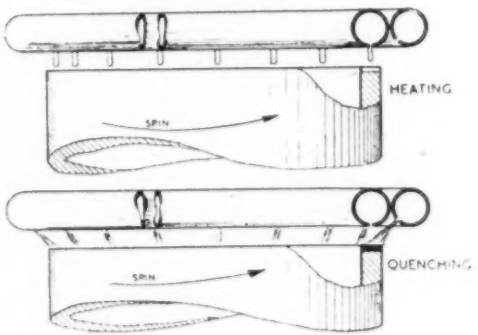
The following elements other than carbon encountered in alloy steels for flame hardening are shown below in order of decreasing effect on hardenability: Vanadium, tungsten, molybdenum, chromium, manganese, nickel.

The effects of these elements in hardening and toughening the material can occur through: (1)



4 LEFT *Progressive method for large gears*

5 BELOW *Edge hardening by the spin method, a variation of the consecutive technique*



of a wearing ring of alloy steel. Such an operation would take some ten hours, as against the present average of two hours for the five groove pistons.

Another interesting example of the application of the progressive method is shown in Fig 2 where a gudgeon pin is being treated. Here we can see ingenious use being made of an old lathe, the headstock rotating the workpiece and the saddle carrying the ring burner with its integral quench and the all-important injector-type blowpipes. These ring burners are standard equipment and sizes ranging from 1—12 in are available.

For hardening shafts, a vertical arrangement such as that shown in Fig 1 can be economical in floor space. The shaft is being rotated on a vertical axis encompassed by a ring of burners traversing upwards and closely followed by a ring of quenching jets.

With a suitable set-up, an internal cylindrical surface is as readily hardened as the external face. The modern solution to the problems caused by earth subsidence due to mining is to crush unwanted slag and pump it back into disused mine workings. As can be imagined, the pipes used to convey the slag are subject to heavy abrasive action, and flame hardening is being used to combat the critical wear problem. The pipes are rotated horizontally and rows of burners and quench jets are mounted on the end of a long ram which is traversed through the pipe by means of a lead screw. Owing to the confined space in which the burners operate in this case they are water-cooled, and compressed air is supplied to the combustion area to make up for the lack of atmospheric oxygen inside the pipe. Even tapered sections are hardened successfully, and other variants of the cylindrical contour can be handled with special jigging.

Many motor-car components such as crankshaft journals, cams, camshaft and steering racks are flame hardened as standard production. One of the most interesting of the applications in the motor industry is the hardening of starter rings produced by a Midlands manufacturer for car and oil engines. This company has wholeheartedly adopted the process to combat the increased wear on these parts caused by the high compression of modern engines. The machine developed by this manufacturer (Fig 3) illustrates that specific design for flame hardening can produce an excellent automatic set-up. This is an example of the consecutive method where the rotating ring is heated by six oxy-acetylene burners and then lowered into the quenching bath. The burners are angled to cover the full width of the ring.

Agricultural equipment is another sphere in which the wear-resistant characteristics of flame hardening have been fully appreciated. The farmer of today relies more and more on mechanical implements to maintain and increase the productivity of his land. This means tough work for the machines and parts most susceptible to wear are flame hardened. An example of the adaptability of flame hardening and its effectiveness is shown by a method used by an agricultural machinery manufacturer to harden bull gears and pinions. The gear (20 in dia by 2 in wide, 4D P 80 teeth) was rotated at high speed with

Solid solution hardening of ferrite, (2) formation of complex carbides, (3) formation of intermediate compounds with iron, (4) effect due to changes in the temperatures of the critical range, carbon content of the eutectoid, and critical cooling velocity.

The following is a brief summary of the effects of these alloying elements: (1) *Manganese* Usually present in all steels up to about 0·8%. It hardens the ferrite, and has a moderate carbide-forming tendency. In quite small amounts it increases the hardenability by decreasing the critical cooling rate.

(2) *Chromium* Has unlimited solid solubility in iron and forms carbides. It is similar to manganese in decreasing the critical cooling rate.

(3) *Molybdenum* Increases hardenability strongly and raises the temperature of a given steel at which grain growth begins.

(4) *Vanadium* Increases the hardenability very strongly and also restricts grain growth.

(5) *Nickel* Increases hardenability only slightly up to about 10%. Its main effect is to toughen by solid solution hardening.

(6) *Tungsten* Increases hardenability strongly in small quantities and has a strong carbide-forming tendency.

Cast iron

Provided that the combined carbon content is over 0·40%, flame hardening can be applied. As in the case of cast steel, the decarbonized surface should be removed before hardening is attempted. Plain cast irons respond quite well, the alloyed irons better according to composition. From the hardening characteristics of plain and alloy cast irons, it will be found that the lower silicon or lower total carbon irons respond best, and that lowering the total carbon is more effective than lowering the silicon.

The choice of an alloyed cast iron composition for flame hardening may materially be influenced by the selection of a desirable balance of physical properties, such as machinability, fine grain, toughness, strength, rigidity, etc, which are included in the main body or core of the casting.

Hardenability-test results on Ni-Mo and Ni-Cr-Mo irons show considerably greater hardness penetrations for these irons as compared with the unalloyed irons, since, in flame hardening, the flame has a limited time in which to act, and cast irons containing a small amount of the transformation-retarding alloys harden with greater certainty. Furthermore, alloys which lower the critical ranges assist in producing a greater depth of penetration for a given temperature, because the temperature gradient from flame temperature at the surface to critical temperature below the surface spreads over a greater depth.

It is also evident that the lower the temperature to which the piece is heated, the less will be distortion upon quenching. Since nickel and manganese lower the critical temperature range, while silicon, for example, raises it, obviously, the optimum cast iron compositions for flame hardening contain as much of the former type of elements as practicable with others reduced to essential or necessary amounts. These considerations indicate a general specification for good flame-hardening cast iron as: TC 3·3% max; Si 1·0% min to 2·0% max; Mn 0·60% min to 1·0% max; Ni 1·0% min to 2·0% max; and 0·75% max of Cr-Mo-V.

Grey cast iron can, under certain conditions, be quite successfully flame hardened; the general structure of this material is grains of steel in finely dispersed free carbon. Thus, its hardenability depends on the chemical composition of the steel grains and the proportion of combined carbon to total carbon.

Pearlitic cast irons with a total carbon content of 3% and a combined carbon content of 0·6—0·9% are particularly suitable, due to their homogeneous graphite distribution.

Radio-frequency induction heaters

concluded from page 147

ficiently well understood to be applied by non-specialists, the industry will not have attained the status of a fully commercial tool supplier.

In so far as early enthusiasm led to a rapid if empirical development of RF-induction heating and incidentally stimulated developments in competing processes beneficial results were obtained. Experience, however, has shown that induction heating is only economic in a small proportion of metal-heating operations. It is to be hoped that further experience will lead to a truer appreciation of the real advantages of RF heating.

Reference

(1) 'Radio-frequency heating,' p 55, George Allen & Unwin, London, 1949.

' Responsibility ' conference

Sir John Hunt, leader of the British expedition to Mount Everest in 1952-53, was chairman of the week-end residential conference which the United Steel Companies Ltd held for 110 apprentices and junior operatives at Cambridge last month. Now in its fourth successive year, the conference was again on the theme of ' responsibility.' During their stay at Downing College, the junior employees heard talks given by industrial and educational authorities and took part in discussion groups.

TITANIUM

With the reduced demand for titanium resulting from cuts in aircraft production in the defence programmes of the U K and the U S, it is interesting to consider the properties and potentialities of this metal and its alloys for other possible applications. The following review of current American practice is based on an article by John L. Everhart in 'Materials in Design Engineering,' October, 1957

TITANIUM can be considered to have reached commercial production in 1952 with an output of about 1,000 tons of sponge. Since that time sponge production has practically doubled each year and by the end of 1956 had reached 14,000 tons. With the entry of new producers, this figure is expected to reach 20,000 to 30,000 tons by the end of 1957, although reduced demand will probably hold output near the lower figure. Accompanying these production increases have been reductions in sponge prices and in mill-product prices.

The latest reductions reflect, however, not only economies resulting from an increased scale of operations but also a reduction in demand. With the cutback in defence spending and cancellation of certain aircraft and missile schedules, defence demands for titanium were curtailed. This is a serious blow to an industry whose product is used almost exclusively in defence.

Only about 4% of the output of titanium is currently used industrially in spite of its advantages of high strength-to-density ratio and excellent corrosion resistance, particularly to oxidizing environments. This is not an unusual condition, however, since engineers must be shown the advantages of a material before they will adopt it. It takes time to prove that a material will save money, in spite of relatively high initial cost, and the results of prototype installations made several years ago are just being evaluated.

It is becoming apparent that, in spite of a combination of high sponge price, wide range between sponge and mill product price, and cost of fabrication, there are civilian applications, particularly for corrosion resistance, in which titanium is truly competitive at present prices.

Production methods

Numerous attempts have been made to develop other methods of production, but most commercial titanium is still produced by the Kroll process (reduction of titanium tetrachloride by magnesium), although reduction of the tetrachloride by sodium is gaining favour. Iodide titanium is produced on a relatively small scale but has no present commercial uses. Electrolytic methods have not been developed to the point where they are commercially significant.

In both the Kroll and sodium processes titanium is obtained in sponge form and must be consolidated to obtain a product suitable for further working. Currently arc melting processes are employed commercially to produce a suitable ingot. A combination of hot and cold working produces the desired shape after melting. Commercial titanium is available in plate, sheet, strip, rod, bar, forgings, tubing, pipe and pipe fittings, wire, wire cloth and special shapes. Although the metal is highly reactive with gases and mould materials at elevated temperatures, these problems have been overcome sufficiently to permit the production of various parts on a limited scale by special casting techniques.

Titanium can also be obtained as a surface on other metals. Cladding by rolling can be performed and availability of carbon steel clad with titanium has been announced recently. Plating of titanium on other metals is still in the development stage.

Several grades of commercial titanium are currently in production, their properties varying with the purity of the material—especially with the nitrogen, oxygen and carbon content and possibly with the hydrogen content. Because of analytical difficulties, commercial grades are generally based on yield or tensile strength. The Aeronautical Materials Specifications of three grades have minimum yield strengths of 40,000, 55,000 and 70,000 lb/sq in respectively.

Although a great many alloy compositions have been investigated in the laboratory, only a few are available commercially at present. These can be divided roughly into three groups: (1) Those developed for use as flat products, bar and forgings include: 5 Al—2·5 Sn; 6 Al—4 V; 2 Fe—2 Cr—2 Mo; 3 Mn—1·5 Al; and 3·25 Mn—2·25 Al. (2) Those developed primarily for bar and forgings include: 3 Al—5 Cr; 5 Al—2·75 Cr—1·25 Fe; 5 Al—1·5 Fe—1·4 Cr—1·2 Mo; and 4 Mn—4 Al. (3) Those developed primarily for flat products —including 8 Mn and the semi-commercial alloys, 6·5 Al—3·75 Mo and 2·5 Al—16 V.

In general, these alloys contain combinations of iron, aluminium, chromium, manganese, molyb-

denum, tin and vanadium. Elements such as iron, chromium, vanadium, molybdenum and manganese tend to stabilize the high-temperature modification (the β phase) of titanium and to produce alloys that are hardenable by heat treatment. Aluminium, tin, nitrogen and oxygen tend to strengthen the low-temperature modification (the α phase).

Physical and mechanical properties

Some of the physical and mechanical properties of titanium and the commercial alloys are given in Tables I—IV. Melting point of the metal is higher than those of any of the metals currently in use as constructional materials, and density is intermediate between those of aluminium and steel. Electrical resistivities of titanium and the stainless steels are similar. Modulus of elasticity of titanium is somewhat more than half that of steels, and coefficient of expansion is less than half that of austenitic stainless steels.

Mechanical properties

Titanium is a very active metal and readily dissolves carbon, oxygen and nitrogen. All three strengthen the metal, oxygen and nitrogen having

TABLE II *Stress rupture properties of titanium*

Type	Stress (1,000 lb/sq in) to produce rupture in 1,000 h			
	400°F	600°F	800°F	1,000°F
Commercial titanium:				
55,000 lb/sq in ..	42	36	10	4
70,000 ,, ..	44	32	16	5
Titanium alloys:				
4 Al-4 Mn ..	110	95	46·5	—
5 Al-2·5 Sn ..	76	65	58	20
6 Al-4 V (annealed)	—	90*	40†	20‡
6 Al-4 V (heat treated)	—	100*	65†	23‡
8 Mn	100	91	26	—

* 750°F † 850°F ‡ 950°F

TABLE III *Creep properties of titanium at 750°F*

Type	Stress, 1,000 lb/sq in	Duration, h	Creep rate, in/h
Commercial titanium:			
70,000 lb/sq in ..	20	—	1×10^{-6}
Titanium alloys:			
3 Al-5 Cr ..	50	300	15×10^{-6}
4 Al-4 Mn ..	50	300	19×10^{-6}
6 Al-4 V ..	50	300	7×10^{-6}
8 Mn	30	—	1×10^{-6}

TABLE I *Nominal mechanical properties of titanium at room temperature*

Type	Form	Heat treatment	Yield strength, (0·2% offset), 1,000 lb/sq in	Tensile strength, 1,000 lb/sq in	Elong (2 in), %	Red of area, %	Rockwell hardness	Shear strength, 1,000 lb/sq in	Impact strength, (Charpy V-notch), ft-lb
Commercial titanium: (lb/sq in)									
40,000	Sheet	Annealed	50	65—70	26	50	A53	48	—
55,000	,,	,,	65	80—85	24	50	A59	55	—
70,000	,,	,,	80	90—100	20	42	A60	65	—
Commercial alloys:									
3 Al-5 Cr	Bar, 1-in	Ann 1 h, 1,300°F	145	155	13*	35	C32	—	13
4 Al-4 Mn	,,	Ann 1 h, 1,300°F	135	145	14*	35	C32	102	14—17
5 Al-2·75 Cr -1·25 Fe	,, 1-in	Ann 1 h, 1,450°F	158	164	15	40	C36	—	10—15
	,, 1-in	½ h, 1,450°F, wq; 6 h 900°F	175	185	10	20	C39	—	—
5 Al-1·5 Fe-1·5Cr-1·2Mo	,, 2-in	Mill annealed	140	155	15	35	C36	—	14
		Heat treated	173	180	15	25	C40	—	12
5 Al-2·5 Sn	Sheet, bar	Annealed	120	125	18	40	C30—35	73	—
6 Al-4 V	Bar, 1-in	Ann ½ h, 1,500°F	130	140	13	40	C33	—	15—25
	,, 1-in	½ h, 1,750°F, wq, 2 h, 1,000°F	150	170	13	14	C38	—	—
	Sheet	Ann 1 h fc to 1,100°F, ac	125	135	12	—	—	—	—
2 Fe-2 Cr-2 Mo	Bar	Mill annealed	120 min	130 min	15 min	25 min	C36 max	—	—
	Sheet	,, ,,	110—140	120 min	12 min	—	—	—	—
8 Mn	,,	Ann 1 h, 1,250°F fc to 900°F	120	135	15	—	A60	—	—
3·25 Mn-2·25 Al	,,	Annealed	120	132	16	—	—	—	—

* Elongation in 1 in.

TABLE IV *Fatigue properties of titanium**

Type	Tensile strength, 1,000 lb/sq in	Fatigue strength, 1,000 lb/sq in	Endurance ratio
Commercial titanium ..	100	60	0·60
3 Al-5 Cr	155	85	0·55
4 Al-4 Mn (annealed) ..	150	90	0·60
4 Al-4 Mn (heat treated)	174	106	0·61
5 Al-1·5 Fe-1·5 Cr-1·2 Mo	155	100	0·65
5 Al-2·75 Cr-1·25 Fe (annealed)	164	92	0·56
6 Al-4 V	136	69	0·55

* Unnotched specimens. Endurance limit for 10^8 cycles except 4 Al-4 Mn alloy (10^7)

the most pronounced effects. Control of the content of these three elements is a problem in obtaining satisfactory ingots, and variations in the sponge cause considerable differences in the mechanical properties of commercial titanium.

The high melting point of titanium led to the idea that the metal would be suitable for applications at high temperatures. Unfortunately this is not the case. Both oxygen and nitrogen are absorbed by titanium at high temperatures. Below 1,100 F a protective oxide film is formed on unalloyed titanium and the oxidation rate decreases with time; above 1,100 F a protective scale is not formed and penetration of oxygen occurs at rates that are sufficient to shorten significantly the useful life of a component and to cause fabricating problems. Present commercial alloys scale at rates that are at least equal to, and may be greater than, those for the unalloyed metal. It does not appear that titanium alloys will be useful for continuous service at temperatures above 1,000 F unless some means of protecting the surface from oxidation is devised. At present some producers consider 800 F as the upper limit for continuous service and 2,000 F the limit for intermittent service.

In general, commercial titanium is reasonably ductile and insensitive to notches, although some loss in ductility is apparent at low temperatures with severe notches (such as the V notch used in the Charpy test). The alpha alloys, such as 5 Al—2·5 Sn, are more sensitive to notches than commercially pure material. The alpha-beta alloys in the annealed condition are not notch sensitive at room temperature, but show increasing tendencies toward transitional behaviour, as occurs in carbon steels, as the beta phase increases. These alpha-beta alloys become increasingly notch sensitive when heat treated to strength levels above 150,000 lb/sq in.

Certain impurities affect notch sensitivity. Carbon, oxygen and nitrogen are detrimental to some degree, but the element most responsible for embrittlement is hydrogen. This embrittlement becomes particularly severe in the presence of a notch at temperatures below 200 F, and the most sensitive method for the evaluation of embrittlement of titanium and its alloys is a notch impact test. The fatigue strengths compare favourably with those of steels when the determination is made on standard polished specimens. The ratios of fatigue strength to tensile strength for some of the titanium alloys are higher than steels.

Titanium and its alloys appear to have excellent properties for applications involving cyclic stresses in corrosive environments. Endurance tests made in air and sea water indicate, if anything, that fatigue strength in sea water is higher than in air.

Corrosion resistance

The most outstanding corrosion attribute of titanium is its resistance to salt solutions; with the exception of aluminium chloride and high concentrations of zinc chloride, unstressed titanium seems to be completely resistant to corrosion by salts. Salts such as ferric chloride have even inhibited attack by various mineral acids. The metal is particularly resistant to attack by sea water and is not pitted by stagnation in crevices, under moist salt crystals, or under fouling growths.

Titanium is resistant to oxidizing acids such as nitric, chromic and aqua regia, to dilute hydrochloric and to most organic acids at room temperature. It is attacked by concentrations over 4% of hydrochloric acid, the rate increasing with the temperature. The metal is not resistant to hydrofluoric, sulphuric, oxalic and formic acids. These acids also produce crevice corrosion of titanium under some conditions, although the metal has good resistance to crevice corrosion in most media.

Titanium is resistant to dilute alkalis, but is attacked by moderately concentrated solutions. No information is available on the susceptibility of titanium to caustic embrittlement.

Solution potential studies show that titanium is cathodic to most of the metals used in aircraft construction. Service experience has shown that corrosion rates of magnesium, aluminium and carbon and low-alloy steels can be more than doubled when coupled with titanium in sea water. Stainless steel resists galvanic corrosion when coupled with titanium. As used in aircraft, titanium accelerates the corrosion of aluminium or magnesium to which it is coupled, the effect being similar to that obtained when stainless steel is coupled to these metals.

Considerable service testing has been carried out in the chemical and process industries, particularly for handling corrosive chloride solutions, and results have indicated a definite field of application for the metal even at its present prices. However, there

are so many factors affecting corrosion rates that tests should be made under service conditions before the metal is selected for applications involving corrosion.

Fabrication procedure

Titanium and its alloys can be fabricated by sheet metal forming methods, by forging and, to a limited extent, by casting. With increasing knowledge of the properties many of the early difficulties have been overcome. Uniformity of properties of sheet material has improved greatly, but fabricators still say that non-uniformity is one of the major problems in handling titanium. Apparently there is still too much variation in directional properties, sheet thickness and flatness, all of which are important in forming sheet. High yield strengths are also blamed for fabricating difficulties.

One important problem in the forming of titanium sheet is that, whereas the limit of uniform elongation of commercial titanium alloys is about 7% for annealed material and 8 to 12% for solution-treated materials, metal forming machinery and processes were developed for materials having uniform elongation values greater than 12%. Considerable work is required to adapt available equipment to the forming of titanium. The material and its alloys can be bent in the power brake using methods developed for stainless steel. Springback at room temperature can be compared with that encountered in bending cold-worked stainless. Hot forming is necessary for tight bends or small-bend radii; temperatures in the range 500 to 600°F are satisfactory for titanium and its alloys.

Annealed commercial titanium sheet up to 0·095-in thick can take a cold bend of 180 deg on a radius of $\frac{1}{2}$ T when bent parallel to the rolling direction, and on a radius of $\frac{3}{4}$ T when bent perpendicular to the rolling direction. Blanking commercially pure titanium sheet on a punch press is similar to blanking 18-8 stainless steel in the $\frac{1}{4}$ hard condition, whereas the alloys may be compared with $\frac{1}{2}$ hard 18-8. Hammer forming gives best results with materials ranging in thickness from 0·032 to 0·051 in. Stretch forming is one of the most successful forming operations. Cold stretching at slow uniform rates with a maximum extension of about 13% is generally satisfactory for commercially pure material and the 8 Mn alloy. Springback of commercial titanium has been compared with that of half-hard stainless steel; in general, the alloys have greater springback. Spinning has been done at elevated temperatures in the range of 1,000—1,200°F using conventional methods. Drawing can be done cold or hot, depending on the severity of the operation, but most parts are formed at 500—600°F; alloy parts are generally drawn at 900—1,100°F.

Forgings

Forging of titanium and its alloys has reached the production stage. In flow characteristics it is closer to aluminium than it is to steel. Titanium alloys are comparable with 7075 aluminium in forging characteristics and the same equipment can be used. Differences in shrinkage characteristics require that special dies be used. Because of rapid work hardening it is extremely difficult to forge thin titanium sections unless the dies are specially designed.

Some organizations recommend that the upper temperature limit for forging be 1,800°F, because the rate of penetration of oxygen and nitrogen into the metal becomes very rapid at higher temperatures and the resulting scaling and surface hardening can become a serious problem. Others prefer to set the upper limit at 1,700°F. Forging of most alloys should be continued until the temperature drops to 1,300—1,400°F if the equipment is sufficiently rugged, as the mechanical properties of the part are improved by this procedure.

Small reductions can be made by cold swaging, but care is required in this operation. The principal forging alloys are 4 Al—4 Mn, 6 Al—4 V and 2 Fe—2 Cr—2 Mo. Commercial titanium is also supplied in forged parts.

Machining and heat treatment

With regard to machining, the type of chip formed in working with titanium alloys resembles that formed by stainless steels, but there is considerable disagreement as to the relative machinability of these materials. It has been said that commercial titanium is more difficult to machine than aluminium alloys and resembles the higher-density stainless steels. On the other hand, some of the alloys compare in machinability with the jet engine disc alloys rather than with the stainless steels. Power requirements are about the same as for 18-8 stainless steels.

Drilling requires low speeds and heavy positive feeds. The unsupported portion of the drill should be as short as possible to provide maximum torsional rigidity and minimize drill run-out.

During heat treatment the crystal structure of titanium changes at 1,625°F from hexagonal close-packed alpha (stable from room temperature to 1,625°F) to body-centred beta (stable above 1,625°F). Slight hardening effects resulting from this structural change have been reported for quenched titanium but have no practical significance. On the other hand, some of the titanium alloys can be hardened.

Additions of alloying elements to titanium

stabilize either the alpha or beta modification. At present the only alpha stabilizers that occur in commercial materials are aluminium, oxygen, nitrogen and carbon. Of these, only aluminium is added intentionally, the others occurring as impurities. The only commercial alpha alloy is 5 Al—2·5 Sn; in this alloy the tin appears to be neutral, stabilizing neither alpha nor beta.

The remaining commercial alloys contain iron, chromium, vanadium, molybdenum and or manganese in various combinations, each of which stabilizes the beta modification so that some of this phase is retained to or below room temperature. These alloys are mixtures of alpha and beta titanium. They are modified but not changed basically by the addition of elements that strengthen the alpha phase, such as aluminium, but benefits obtained from the alpha phase strengtheners are more apparent at elevated temperatures than at room temperature, *i e* alloys containing alpha strengtheners retain their strength at higher temperatures than alloys not containing these elements.

Surface hardening

When titanium-base materials are heated to high temperatures in air, hardening occurs by absorption of oxygen and nitrogen. Investigation of various procedures has shown that titanium can be nitrided to form a useful case, but penetration of oxygen is so rapid that embrittlement of the core occurs.

Titanium can be nitrided by treatment either with pure nitrogen or with ammonia. However, the base metal is somewhat embrittled by both treatments. The cases formed have shown good wear resistance in tests. Carbonitriding by treating titanium with mixtures of propane and ammonia, or propane and nitrogen, also produces hard cases, These cases are essentially nitride cases, however. and have characteristics similar to those produced by nitriding.

Applications

At the present time the only important non-military use of titanium is in commercial aircraft, in which the high strength-to-weight ratio gives the metal an advantage in spite of its high price. Use of the metal in commercial aircraft will probably increase with reductions in price, but quantity requirements can never be large enough to sustain the titanium-producing industry.

Future applications of titanium will probably be based on its excellent resistance to corrosion in certain environments. Recognizing this fact, the producers have put considerable effort during the past three years into the development of forms that have primary application in industrial fields. These include piping and pipe fittings in IPS sizes, spray nozzles, deep-drawn large hemispheres, spun and disced cylindrical heads, wire cloth, valve and pump parts. Most of the work has been done on commercially pure titanium because it has better corrosion resistance than the alloys, because more is known about the effects of specific environments on its resistance, and because it can be more radily formed and joined.

Various installations of commercial titanium have been made in the chemical and process industries, and test data are being accumulated in plant operations. At present prices it appears that use of the metal on a commercial scale will be limited to applications in which other materials are grossly inadequate. However, a number of applications have been developed in which titanium is competitive.

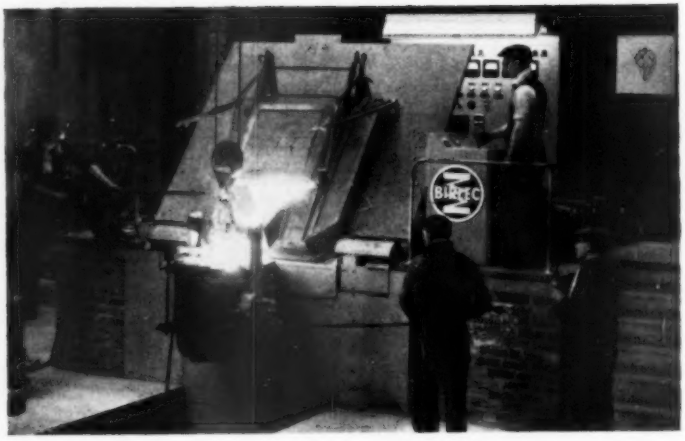
Pneumatic steelmaking plants

THE ADVENT of the tonnage oxygen plant is bringing about a revolution in methods of steelmaking, both on the Continent and, more recently, in this country. Interest is not confined only to steelmakers—plant manufacturers are actively engaged in equipping themselves to meet the demands of industry. Head Wrightson & Co Ltd have taken advantage of continental progress in this field by allying themselves to the German firm of Pintsch-BAMAG.

Active contacts are being maintained (in conjunction with BAMAG) with continental steelmaking plants—and, in particular, with Prof Kalling (the inventor of the Kaldo rotating converter) at Domnarfvet.

Much of the plant for these new processes is of massive construction, and the Middlesbrough works has long been able to machine parts up to 100 tons in weight. The first bay, 100 ft span by 400 ft long, of a new heavy fabricating shop, with a lift of 100 tons, is now approaching completion at Thornaby, and is expected to be in use early in May.

New furnace for alloy steels



View of the furnace during pouring

INCA STEEL CO LTD (member of the C. R. Denton Steel & Tool Co Group) has in the past used conventional methods to produce a wide range of tool and die, stainless and high-speed steels. Now, the world's first mains-frequency coreless induction furnace for the regular production of high-speed steel has been installed by Birlec Ltd at the Magnum Works.

Similar Birlec furnaces have been used for some time in non-ferrous and iron foundries, but the Inca installation is the first example to be used by a British steelmaker for the production of alloy steel. The opinion had been held by steelmakers that turbulence in the molten metal, which is characteristic of this furnace, would cause serious inclusions in high-grade steels. Consequently, Mr. Edgar Denton and Mr. William Kelsey, two directors of the company, visited both Germany and Denmark in 1955 and 1956 to study at first hand the technical and operational methods which were being explored on the Continent. The firm of Otto Junker G m b H of Lammersdorf, Germany, had already made considerable progress and an agreement between this firm and Birlec gave the opportunity for developing a British-built mains-frequency coreless induction furnace specifically for melting high-grade alloy steels and high-speed steels.

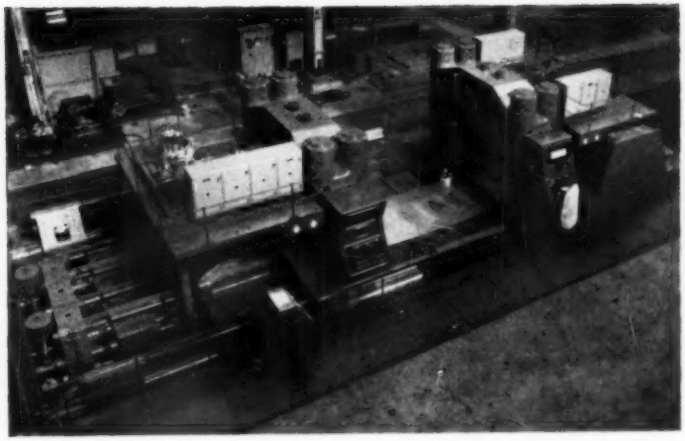
After carefully considering the relevant technical and economical data available, Inca decided to embark on an installation and placed an order with Birlec for the furnace which has recently been installed and put into successful operation. The technical melting staff have so far overcome the inevitable teething troubles, and have not met with serious non-metallic inclusions in the steel. The ingots and finished bars produced have exceeded all theoretical expectations, and the cleanliness of the steel bears favourable comparison with any steels produced by established methods.

The new Birlec furnace has a capacity of 1½ tons, and a power input of 450 kW can be applied, giving a maximum output of the order of ½ ton/h of prime high-speed steel ingots. Flexible power input control enables metal temperature to be closely adjusted.

The furnace is charged with selected scrap, a heel of molten metal being retained from each heat as the basis for the following charge. Mounted flush with a working platform about 4 ft above the foundry floor, the furnace is tilted by hydraulic rams, served by a self-contained pressure unit. A bottom-pouring ladle transfers the metal to the ingot moulds.

The application of the mains-frequency coreless induction furnace to high-speed steel production is a new and important step. The performance of the Inca installation will be watched with much interest, but it can be said already that it appears to be fully equal to that of a conventional high-frequency furnace and, in addition, floor space and capital costs are much more favourable. The prime consideration, however, is economy of operation and, in this respect, the new furnace is outstanding, principally because a frequency converter is not required, so that both power consumption and maintenance are reduced to a minimum.

Several hundred installations at home and abroad are already in regular production on ferrous and non-ferrous alloys, but the latest step by Inca Steel Co opens up a new field for the production of high-grade alloy steels.



Aluminium plate production

View of the 4,000-ton plate stretcher

New development at the Northern Aluminium Company

MORE THAN half a million pounds' worth of new machinery and equipment has gone into service at the Rogerstone, Monmouthshire, works of Northern Aluminium Co Ltd. The result of several years of development and two years of installation work, the new equipment extends the company's aluminium fabricating plant and provides new facilities for the production of high-quality aluminium plate. There are two distinct developments, to meet diverse industrial needs—the aircraft industry's demand for thick, high-strength aluminium alloy plate for machining into integrally-stiffened wing skins and similar aircraft parts; and the shipbuilding industry's call for aluminium plate in the medium-strength alloys, in sizes wider than have hitherto been available.

Plate for the aircraft industry

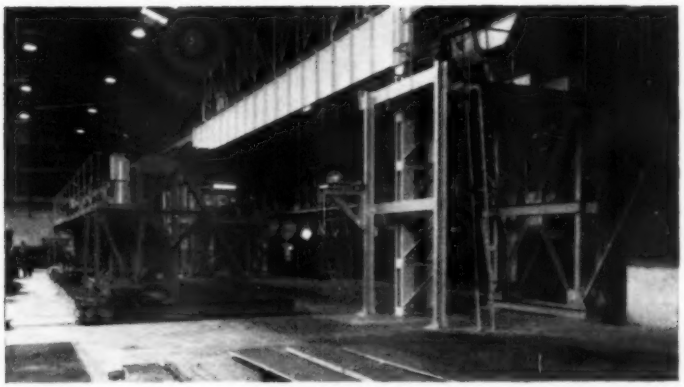
In recent years, a new technique for the fabrication of certain stressed parts of high-performance aircraft has had to be introduced to meet strength requirements. Wing skins, tail surfaces and similar parts, instead of being made as a riveted assembly of small components, are machined, complete with stiffening members, from large pieces of thick plate. For this method of production, the first requirement is high-strength aluminium alloy plate, of the right composition, correctly heat-treated to develop the necessary mechanical properties, and with a low level of residual internal stress, to give freedom from distortion when it is machined. Moreover, in view of the structural demands made in service, the absence of small undetected flaws in the metal must be assured.

Heat treatment

Noral aircraft plate is produced by first hot-rolling cast (or, in special cases, preforged) ingots; for the time being the existing rolling capacity of the works will be adequate for this purpose. Heat treatment will now, however, be carried out in a new bottom-loading furnace designed and built by Stordy Engineering Ltd to meet the detailed requirements laid down by Northern's general engineering department. It is of particular interest in being of the bottom-loading type, with a quench tank immediately below the furnace chamber. This design was chosen as giving the best answer to the problems arising in heat-treating aluminium alloy plate of the sizes contemplated.

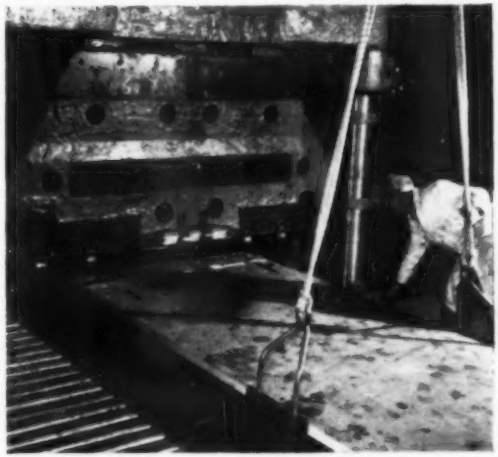
The furnace is called on for the heat treatment (*i e* both solution treatment and artificial ageing, as well as annealing) of aluminium alloy plate. Its capacity is nearly 20 tons of plate for ageing at temperatures up to 200°C, without quenching; 10 tons for solution heat treatment up to 550°C, with a slow quench; and 5 tons for solution treatment up to 550°C, with a high-speed quench. It forms an essential part of the complete production facilities and, like the rest of the equipment, is designed to handle plate up to 55 ft long, 10 ft wide and 6 in thick.

The furnace is electrically powered and fully air-circulated, the heater batteries and fans being mounted at each end, outside the furnace chamber.



LEFT *The new Stordy heat-treatment furnace of the bottom-loading type*

BELOW *Plate being put into position for stretching in the Loewy stretcher*



members, at 4 ft 6 in pitch, in which the head is locked according to the length of the plate.

Adjustment of the position of the head is made in a series of 4 ft 6 in steps, by ram-operated tow-bars sliding inside the compression members. In this operation tow-bar pins fitted in the head engage with the tow-bar for the movement of the head, and then disengage to allow the tow-bar to return for the next step. When the head is in the required position, overstroke rams facilitate the engagement of the anchor pins in the holes in the compression members.

The two main stretcher rams are of 36½ in dia, and have a 7 ft 6 in stroke. To effect a fast advance and return of the main head when not stretching, the main cylinders are not used; instead the head is moved by double-acting 8-in-dia rams acting on the main head. The cylinders in which these advance-and-return rams operate are attached by long tie-bolts to the main cylinders.

The main compression members are held in alignment with each other, and with the foundation, by self-centring rams arranged at the tow-bar end. Tie rods connect the centring rams to the compression members and to the foundation. To prevent any possibility of danger to the operating crew caused by the presence of the open anchor pin holes, each compression column is covered throughout its length by a wooden slat apron, arranged to pass around guides and rollers over the anchor pin gear.

A continuous disappearing apron is attached to the adjustable head. This serves to fill in the space between the heads and also acts as a support for plate prior to stretching. For the latter purpose it is fitted with free-running rollers on which the plate can be moved longitudinally. Once the plate is placed on the apron, manipulation into the grip heads is entirely independent of outside help. Devices are provided on each head for raising the plate ends to facilitate entry into the jaws, and also for plate centring. Lengthwise positioning is by means of plate locating stops within the jaws.

The grip jaws of both heads are in ten segments, which do not have to be changed for different plate thicknesses. Each top and bottom pair of segments is mechanically centred, and all are able to move to a small degree relative to each other to accommodate a degree of variation in the thickness of a plate. To give the heavy initial ' bite ' necessary to hold the plate the jaws are moved by 400-ton hydraulic rams. The depth of penetration of the plate in the head, and hence the length of grip, is determined by the plate locating device, which has two appropriate pre-set positions. These positions are selected according to the width and thickness of plate. In addition to jaw segment movement, the main head is capable of a limited angular movement to allow it to take plate that might be slightly wavy along one edge. This feature also tends to make the gripping of the plate easier.

A general feature of the hydraulic system of the

The total heater rating is 1,494 kW; each heater battery has three sections with independent switching to allow fine temperature control. Four fans, two at each end of the furnace, are used for circulating air, which is drawn through stainless-steel ducting from the top of the furnace chamber, passing through the fans, then through the heaters, from which it is again ducted to the furnace chamber. Each fan is driven through vee-belting by a 40-h p motor.

The furnace is of special stainless-steel-lined construction, entirely without refractories. The whole structure is carried in a riveted and bolted steel box girder, supported at each corner by a massive compound stanchion. Asbestos-sealed sliding joints in the furnace casing allow for expansion. The furnace door itself, insulated in the same way as the furnace and similarly lined with stainless steel, is made of a number of 6-ft-square sections joined to make one continuous door. Sealing in the closed position is maintained by asbestos cord, carried in heat-resisting castings round the edge of the door. When the door is closed, this cord is pressed against corresponding castings around the opening in the bottom of the furnace.

The operation of opening or closing the door involves two distinct actions, a moving into position and a sealing or unsealing action. The door is mounted on toggles, which are operated, through linkages, by two hydraulic cylinders and serve to raise or lower the door through a few inches for sealing or unsealing. The whole door and its sealing mechanism are in turn mounted on a carriage, which spans between rails 60 ft apart. To close or open the door, the entire carriage is electrically driven about 8 ft along the rails. When the door is in the closed position, brackets are engaged so that the forces exerted by the sealing operation are carried by the main furnace steelwork and are not transmitted to the door carriage.

The furnace load is carried on seven full-length joists, one piece of plate being supported by each joist. The joists rest on four short transverse bearers, which are attached at their ends to hoist chains. These pass through the roof of the furnace and over pulleys to drums mounted on a shaft at the rear of the furnace. Drive to this shaft, for raising and lowering the load, is provided by a 45-h p d c motor, powered in turn by a motor-generator set with Ward Leonard control. The control gear is set so that all loads are raised into the furnace at 20 ft/min, while lowering can be carried out at 20 ft/min or at the quenching speeds of 90 or 180 ft/min. Safeguards are provided in the control mechanism so that loads weighing over 10 tons can be lowered only at 20 ft/min, and no load weighing over 5 tons can be lowered at the fast quench speed.

A furnace charger, running on rails at each end of the furnace and spanning the quenching tank, is used for loading. The load is placed on the charger by an overhead crane, and is then traversed under the furnace, where the load is transferred to the hoist chains and the charger withdrawn.

The quenching tank, immediately below the furnace and sunk into the floor, is of concrete and measures, overall, 102 ft long, $10\frac{1}{2}$ ft wide and 15 ft deep. Much of this length and width are occupied by circulating pumps and passages, however, and the useful size of the tank for quenching purposes is 60 ft long, 6 ft wide and 15 ft deep. The two axial-flow circulating pumps, which have provision for alteration of impeller blade pitch from floor level without withdrawing the pumps, were supplied by W. H. Allen Sons & Co.

Controlled stretching

The quenching of aluminium alloy plate sets up undesirable internal stresses. These remain in the metal and can cause serious distortion when it is later machined. The most effective means yet found for the removal of these stresses is a controlled stretching operation; in this, the metal must be stretched so as to give a minimum of $1\frac{1}{2}\%$ permanent elongation.

The stretcher, a machine with a rated pull of 4,000 tons, is capable of applying a controlled stretch to light-alloy plate up to 50 ft long, 10 ft wide, up to 6 in thick, and with a maximum cross-section area of 200 sq in. It was designed and built by the Loewy Engineering Co Ltd.

The basic principle around which the stretcher is designed is simple: one end of the plate is gripped in a fixed head, the other end in a sliding head; the sliding head is forced away from the fixed head by the action of two hydraulically-operated rams and, as it moves, the plate is stretched by a predetermined amount.

The stretcher consists of two main compression members, which are placed one each side of the machine; in side-elevation, these are level with the centre-line of stretch. Directly on the ends of the compression members are mounted the two main hydraulic cylinders, with rams bearing on side extensions of the main grip-head. This head is carried on horizontal bearing surfaces, and moves during the action of stretching. The tail grip-head, on the other hand, is fixed relative to the compression members during stretching. So that pieces of plate of various sizes can be accommodated, however, this head is adjustable along the compression members. For this purpose there are nine anchor holes in the compression

dimensional pip-type echo information at the first oscilloscope, telling the operator the depth in the metal at which the flaw has been found and its size. Size is indicated by the amplitude of the trace, while depth is shown by relating the position of the echo on the screen to those echoes received from the top and bottom plate surfaces. The second, the B-scan, enables the operator to see a longitudinal or transverse section of the plate being inspected, the top and bottom surfaces being represented by bright horizontal traces on the screen and defects being indicated by bright spots. By correlating this information with that received at the A-scan, a complete picture of the flaw and its position is obtained.

Plate trimming

When large pieces of material are trimmed to size, difficulty arises in keeping the material squarely, accurately and firmly located relative to the cutting blade. This problem has been overcome in the new saw, built by Wadkin Ltd, by a new method of plate security during cutting.

Surmounting the machine, and completely spanning the plate to be cut, is a single box-section beam, 68 ft in length between its pin supports, 6 ft deep at the centre of its span, and weighing about 20 tons. Within the beam are carried 18 pairs of hydraulic jacks which hold the aluminium plate to the table. The plate is cut by a circular saw which travels beneath the beam, traversing its length; the saw blade is located beneath the centre of the beam's cross-section and projects upwards between plate conveyor tables.

The saw is driven by a 75-h p motor housed in a 14-ft-long saddle, which also carries the 6¼-h p feed motor. The base of the whole machine is 5 ft 5 in below floor level, the saddle-bearing surface being 2 ft 1 in above the base.

For moving plate to be trimmed into position beneath the beam there are seven in-feed and seven out-feed conveyors. The surface height of the conveyors is 2 ft 6 in above floor level. The plate conveyors were built by the Albert Mann Engineering Co Ltd.

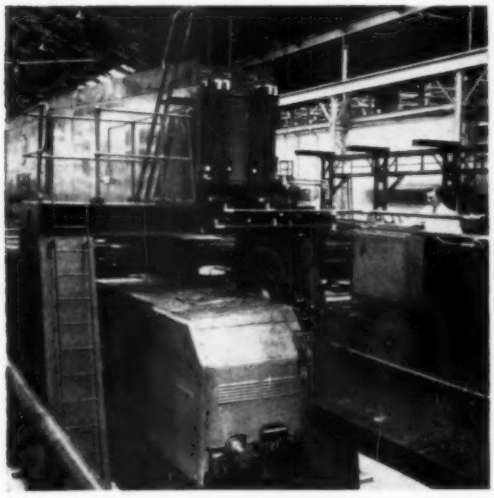
Aluminium plate up to 55 ft long can be sawn with the machine in its present form, and there is provision for ultimate extension to 75 ft. The overall length of the machine is considerably greater, for at the control end the bed is extended so that the saddle can run out clear of the beam support. Arrangements for the disposal of swarf (which is carried away by a drag-link-type conveyor beneath the saw blade) extend the machine at the other end, giving a length of nearly 140 ft overall.

The teeth of the saw blade are tipped with tungsten carbide, and very high feeds and speeds can be employed.

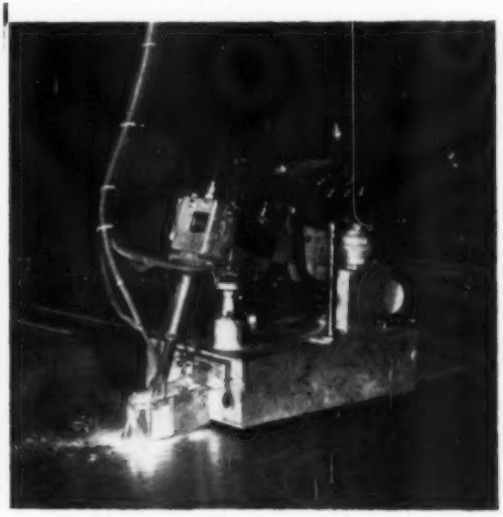
Shipbuilding and other industries

For shipbuilding, and similar industries where sizeable fabrications are built up of plating, the most important feature of the new developments is that aluminium plate will now be available, for the first time in this country, in widths up to 11 ft.

The Wadkin high-speed plate saw. In the foreground can be seen the saddle carrying the sawing disc



Automatic welding equipment in use by a method ensuring freedom from distortion for producing wide plate



stretcher is the necessity for control of two rams widely spaced apart, but required to travel at the same speed. This occurs with the main advance-and-return tow-bar and jaw operating rams. The control is effected by driving the two rams by separate pumps, and controlling the flow from each pump by bleed-off valves operated by a differential mechanical linkage. In this manner cross-wise alignment of the heads is maintained. However, in the case of the main head, a limited amount of free angular movement is allowed (at the beginning of an actual stretching stroke only) before the balance gear comes into play.

The machine has three separate oil hydraulic systems, one on each grip-head, and a main one in the foundation supplying the main cylinders, the advance-and-return cylinders, and the tow-bar rams. The main system is charged by two pumps driven by a 150-h p double-ended motor. These pumps deliver oil at 4,500 lb/sq in, but there is provision for increasing the pressure to 7,000 lb/sq in, to enable the stretcher to give a 6,000-ton pull. There is also a small pump to supply pivot pressure at 400 lb/sq in to the control valves. The hydraulic systems in the grip-heads supply the jaws and the plate lifting, centring and locating devices. On the adjustable head they also supply power for the manipulation of the anchor and tow-bar pins. Two pumps are mounted on each head; one driven by an 18-h p motor supplies oil at 4,500 lb/sq in for the jaw-operating cylinders, the tow-bar and anchor pins on the adjustable head, and pilot pressure at 300 lb/sq in for the control valves. The second pump, driven by a 4-h p motor, delivers oil at 4,500 lb/sq in to the operating cylinders of the plate lifting, centring and locating devices.

All controls necessary for the operation of the stretcher are mounted on control desks, carried on each head. On the main head control desk, in addition to the pistol-grip and push-button hand controls, is a stretch indicator. This shows the length of plate between the jaws, and the amount of elongation applied. The degree of stretch can be pre-set at values from 1—5% and the operation will automatically stop as soon as the pre-set value is reached. As an alternative, provision is made for stretching to a predetermined stress.

An important feature of the machine's design is that it is protected from shock damage should a plate break while being stretched. When the plate breaks, the grip heads are accelerated outwards, and the two broken parts of the plate are projected into the heads. Large pressure-relief valves protect the tow-bar cylinders, the main head advance cylinders and the jaw cylinders, and stop the outward movement of the heads. During the outward movement, the foundation is protected from shock by compression-member centring cylinders, into which are built relief valves. Movement of the whole stretcher structure relative to the foundation is thus possible. Residual shock loads remaining after hydraulic damping are finally transmitted to a pre-stressed concrete beam built into the foundation. The attachment of the stretcher to this beam by means of two tie rods is the only longitudinal fixing for the entire machine. After displacement caused by plate breakage, all parts can be returned hydraulically to the normal position relative to the foundation.

Ultrasonic inspection

Apart from the long-established tests of strength and elongation carried out on specimens of a given material, it must be made certain that no minute local defects remain undiscovered in the metal. Assurance of complete soundness throughout the thickness of the plate is of especial significance when the material is intended for machining into important aircraft parts.

The ultrasonic testing equipment was designed and built by the Curtiss-Wright Co. The 'Immerscope,' as the equipment is called, enables the plate to be inspected in fully immersed conditions—a method that ensures complete examination of the entire plate, except for a thin 'dead' zone comprising the top $\frac{1}{10}$ in of the material under test.

For examination, the plate rests in a tank of water 14 ft wide, 3 ft deep and 54 ft long. The steel tank is made up in 4-ft sections, each section being bolted to its neighbour through a Neoprene joint. The inside of the tank is hot-sprayed with zinc to prevent corrosion.

The probe unit, by which the ultrasonic wave is directed into the metal, is mounted on a carriage which in turn is carried on an aluminium scanner bridge of lattice construction, running on rails at each side of the tank. In this way the whole plan of the tank can be covered by the probe, the carriage traversing the bridge in the same manner as the bridge travels the length of the tank. The probe unit can also be raised and lowered according to the thickness of the plate under examination. The motors for driving the bridge, carriage and probe unit are mounted within the bridge.

Bridge and carriage motions may be automatic, or manually operated by switches, and their speeds are continuously variable from 5—90 ft/min. The controls can be set so that repeated automatic sweeps by the probe unit across the plate can be made by moving either the bridge of the carriage in steps as small as $\frac{1}{8}$ in or as large as 12 in. The operator sits at a control panel remote from the tank and can use either one of two ultrasonic systems or both simultaneously.

Of the two 'scans,' the A-scan supplies two-

NEWS

Steel prices reduced

THE IRON AND STEEL BOARD announced reductions in the maximum prices of many steel products at the end of last month. This has been made possible by the lower costs of imported materials although this saving has been offset to some extent by increases since last July in other costs, mainly abour costs.

Examples of basis price reductions are: Light sections and bars, wire rods, 7*s* 6*d* a ton; plates and heavy sections, 10*s* a ton; strip mill sheets, £1 a ton; cold-rolled strip, £1 15*s* a ton. Strip-mill tinplate is reduced by 6*d* a basis box, but reductions in extras, particularly in the lighter gauges, provide an overall reduction equivalent to 1*s* 1½*d* a basis box (or to about 27*s* 6*d* a ton). Certain other extras and allowances have been amended, some up and some down, to bring them more closely into line with current conditions.

The British iron and steel industry agrees that the Iron and Steel Board's decision to reduce the maximum home trade prices of most steel products is right. The industry is benefiting at present from both the fall in the landed cost of imported materials and the drop in its import requirements. On the other hand, it has been carrying the very substantial increases in home costs which have arisen since steel prices were last adjusted in July, 1957. Some of the increased home costs have been offset within the industry by improved productivity, but the remainder has absorbed a considerable part of the industry's import savings.

The price reductions announced, the first since 1939, should save home steel consumers some £10 million a year, more than 1% of the total consumption figure. It is appreciated that production costs could increase over coming months, but nevertheless, the industry hopes to maintain stable prices in the foreseeable future.

Hungarian steel works to use natural gas

Hungarian engineers are working to adapt the Lenin steel works at Diosgyor, north-east Hungary, by the end of this year to use natural gas piped 240 miles from Rumania for fuelling furnaces.

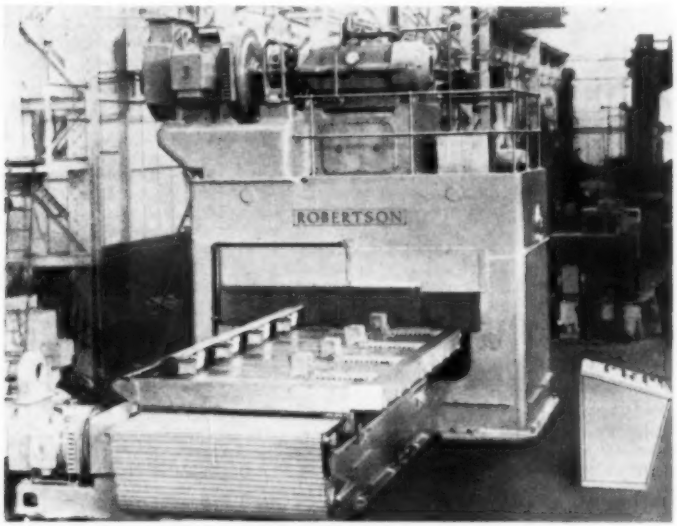
Diosgyor steel works can use 110,000,000 m³ of the 200,000,000 m³ of gas per year that can be supplied, reports the newspaper *Magyar Nemzet*. The extension of the pipeline and convertion work at the foundry will cost an estimated £1,200,000.

Power engineers recently visited Italy to study the use of natural gas as a fuel for furnaces and are shortly to go to the Soviet Union for the same purpose. Experts are also considering whether to use the remaining 90,000,000 m³ of gas at the new Tiszapalkonya power works (at present working on pulverized coal) or at foundries at Ozd, 20 miles further on from Diosgyor.

Ingot milling machine for America

The English Electric Company has recently supplied the complete electrical equipment for a large ingot milling machine manufactured by W. H. A. Robertson & Co Ltd, and ordered by the American Brass Company for its plant at Terre Haute, Indiana, U S A.

Electrical equipment includes a 200 h p d c motor driving the milling cutter and a 6 h p d c motor driving the ingot carriage, both supplied from a Ward-Leonard generator set driven by a 265 h p a c motor. The cutter can be run at any desired speed from 2,000 to 4,000 ft/min. Ingot carriage forward speed is variable with a fast return speed, the cycle of operation being completely automatic. Control and operation of these drives is by push buttons and control switches on a desk adjacent to the milling machine. A contactor panel and various auxiliary drives were also supplied.



The Robertson milling machine which will be used for milling the faces of aluminium and alloy ingots up to a size of 60 in wide by 12 in high by 120 in long, and will remove imperfections from the cast ingots before they are rolled into strip and subsequently into foil. If these imperfections are not removed they show up as serious faults after rolling the material to the finished thickness.

This new product is made by butt-welding two plates together, using specially developed equipment.

Welded Noral plate has been made possible by the successful development of production equipment at the Rogerstone works.

The equipment consists essentially of a 35-ft-long concrete base, carrying the welding jib. The two pieces of plate to be welded are placed flat, edge to edge (with an appropriate welding gap) on the jig, which holds them firmly in place. The overhanging part of one piece of plate is supported on trestles, the other by a plate turnover table. The welding is carried out by an Argonaut welding head operating fully automatically on a self-propelled carriage, and specific techniques have been developed to give consistently sound results, without distortion, for all plate gauges. The welding speed is generally between 15 and 150 in/min.

After completion of the weld, which is made in one pass, the top weld bead is removed and the plate lifted off the welding rig by an overhead crane. The plate turnover mechanism then reverses the plate for removal of the under-bead.

Future plans

Northern Aluminium plans to spend £10,000,000 over the next four years, nearly £8,000,000 of this being for new plant and buildings. The major part of this programme will be the expansion of the company's aluminium rolling mill at Rogerstone, Monmouthshire, raising its annual capacity to 75,000 tons in such a way that a further increase will be possible—at a relatively low cost per ton—to an ultimate capacity of 175,000 tons. The remainder of the investment will be in further modernization of the Banbury and Birmingham works.

In the face of increasing competition from abroad, and the trend for aluminium fabricators to build their own plants in countries that have customarily imported products from the U K, more efficient production methods have become essential. The company believes that these can best be attained by the large modern rolling mill with a high rate of throughput, coupled with the necessary flexibility to handle the diversity of light-alloy products demanded today.

The augmented mill will be equipped for the economic manufacture of a large range of rolled products. Wider and longer plate in aluminium and its medium-strength alloys will become available. Larger sizes of medium-strength alloy sheet will be offered for the more economic construction of road and rail vehicles and for general engineering. A product with significance for the aircraft designer will be massive, heat-treated, high-strength alloy plate. In addition, the cost and quality of the aluminium and 'common' alloy sheet for which the mill is already well equipped will be made more attractive to the building, packaging and other industries that are its main outlets; the increased length of coils will be of value, for instance, to foil rollers.

Principal additions to the plant for this development will include a powerful 12-ft-wide hot mill for 'breaking down' ingots and rolling large plate; the addition of a third stand to the present two-stand hot-finishing mill, with provision for a fourth; and the introduction of hot coiling under tension direct from this mill. Preheating, annealing and remelting furnaces will be among the ancillary equipment installed to serve the new 'hot line,' and cold-rolling facilities will also be augmented.

Electronic melting and casting process

A novel process to melt and cast special metals, such as titanium, zirconium, tantalum, molybdenum and columbium, and proved on a semi-works scale, was recently announced by Stauffer Chemical Company, Mallory-Sharon Metals Corporation, and Temescal Metallurgical Corporation. The process is owned by the three companies which have co-operated in its development. It is said to have advantages over vacuum melting.

The process uses electron bombardment in a high vacuum to melt chemically-active materials which have high melting points. Techniques have been developed which make possible volatilization and removal of certain critical impurities, resulting in final products of high purity with properties not attainable by other methods. The semi-works plant has successfully melted, purified and cast a dozen special metals in water-cooled crucibles with no contamination from the crucible.

Electron beam melting will probably find its greater use in purification of refractory materials and such high-melting metals as columbium, tantalum, molybdenum, beryllium, vanadium and special stainless steel alloys.

London drawing office for United Steel

The United Steel Companies Ltd have decided to set up a central drawing office in London and are equipping premises at 125-127 Victoria Street for this purpose. Recruitment of draughtsmen is now proceeding and it is hoped to employ between 20 and 30 initially. It is intended that the new office should provide facilities for design work on development projects and for detailed drawings of plant and engineering work required by the company's branches in South Yorkshire, Lincolnshire and Cumberland. These works have their own drawing offices, employing a total of about 150 draughtsmen, and the central drawing office will supplement their activities.

Mr R. M. W. Lowe, who was employed until recently in the engineering department at Appleby-Frodingham Steel Company, has been appointed manager of the new drawing office. He will be responsible to Lt-Comdr G. W. Wells, managing director (engineering works) of United Steel and director and general manager of Appleby-Frodingham Steel Company.

BOOKS

Induction and Dielectric Heating

191 pp., 154 figures and 10 tables. Published by the British Electrical Development Association, 2 Savoy Hill, London, W.C.2.

THIS book is the sixth in a series published by the E.D.A., dealing with specialized industrial applications of electricity, having the theme 'Electricity and Productivity.' The particular object of this book is to show management executives how the many new heating problems arising in modern industry may be solved by the application of alternating electric currents for induction or dielectric heating. Emphasis is given to the selectivity, precision, economy, and ease of control of these methods of heating, which, it is claimed, can achieve a uniformly better product with less skill and experience than the traditional methods. The motto of the book is in fact 'heating with machine-tool precision.'

The book is in three parts, dealing respectively with 'induction melting of metals,' 'induction heating for metallurgical purposes,' and 'dielectric heating.' These three sections are prefaced by a short introduction which briefly differentiates between the different methods and applications of alternating current heating. A glossary of the technical terms used appears at the end of the book.

Induction melting of metals is dealt with very briefly in one chapter. After itemizing the advantages of induction melting, short descriptions are given of the two basic types of induction melting furnace, namely the submerged resistor or core-type furnace, and the coreless induction furnace. The former is applicable to the lower melting point metals and particular reference is made to its use for brass and aluminium melting. The coreless induction furnace is shown to be more generally used for ferrous materials and for high melting point non-ferrous metals such as nickel, although it has also proved to be of particular advantage for magnesium melting. A few special applications of the coreless induction furnace are also described, including dual frequency furnaces for controlled stirring, small-scale melting, vacuum melting, and investment precision casting. Throughout this chapter useful data are given on power requirements, melting times, and output for the various types of furnace and application described.

Part two constitutes the largest section of the book and nine chapters are devoted to the many miscellaneous applications of induction heating in the engineering industry. The first chapter in this section (Chapter 2) briefly reviews the principles of induction heating, describes the various types of plant available and gives advice on the location and maintenance of the equipment. Various claims are made regarding the superiority of induction heating from the points of view of rate of heating, absence of scale, precision, automatic control and productivity. These are undoubtedly true in comparison with many conventional methods of heating but they may be open to serious challenge by those familiar and experienced with modern flame hardening machine tools. A few applications of normal mains frequency heating are discussed, including preheating of joints for welding, stress relieving of weldments, forgings and castings, heating for shrinking, heating of non-ferrous billets for extrusion, and heating of press platens for moulding plastics. Greatest emphasis is, however, on high-frequency induction heating, as applied to surface hardening of engineering components, through heating for forging, annealing, and brazing, soldering and welding. Many examples are given of these applications, accompanied by much useful operating data. A final chapter discusses a few miscellaneous applications of a more specialized nature, such as sintering of metal powders, analysis of metals, glass to metal joints, and heating for chemical processing.

Part three deals in four chapters with the nature and applications of dielectric heating. Following a technical discussion on the generation of dielectric heat, consideration is given to the layout of plant and to the precautions to be observed in employing this technique. The applications of dielectric heating in the plastics and in the woodworking industries are considered in turn, followed by a description of several miscellaneous applications. In the growth of the plastics industries, dielectric heating has played an important part and numerous examples are given of its use in the moulding of thermo-setting plastics, welding and fusing of thermo-plastic sheets and bonding of plastics to woven fabrics. Synthetic resin glues of the thermo-setting type have been introduced into the woodworking industries and dielectric heating may be used for the curing of the resins. Examples are given of its use in the manufacture of plywood, laminated products, resin-bonded wood chip board, and assembly of wood components. Miscellaneous applications include the baking of resin-bonded foundry sand cores and resin-bonded shell moulds, vulcanizing of rubber, and the drying of textile yarns, unfired ceramics, and food products.

The book is well written in a clear and easily readable style, and is profusely illustrated with photographs and diagrams which admirably supplement the descriptions in the text. Within the limits set, namely, to stimulate interest from a production engineer's point of view in the possible new lines of approach to heating problems, this book should be successful. A warning does appear in part three of the book which might well have applied to the whole book. This indicates that where existing methods appear satisfactory, very careful consideration must be given to all the factors involved before replacing them. In such a comparatively small and handy volume it was clearly not possible to discuss all the relevant factors fully and some not at all. If, therefore, any of the techniques described in the book appeal to the reader, he will undoubtedly wish to consult experts on his particular problems for a more detailed assessment of his requirements.

E. INESON

Brittle Behaviour of Engineering Structures

By Earl R. Parker. Chapman & Hall, London. 28*s*. net.

THIS book is a timely attempt to present a scientific account of the causes and factors affecting the catastrophic fracture in mild-steel structures, a subject generally referred to as 'brittle fracture.' Amongst the very large number of papers and articles on this subject which have been published in the last 15 years, a number have given excessive emphasis to particular aspects of the subject and to many the subject has remained a mystery, isolated from general metallurgical theories. The author of this book is, therefore, to be commended on the scope of the work and his attempt to present the phenomenon of 'brittle fracture' as part of a general study of the deformation and fracture of metals. The book is logically arranged; two of the early chapters are devoted to a discussion of the general concepts and theories of fractures in metals in which the conditions for brittle cleavage

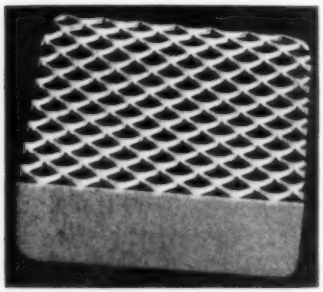
Wilmot Breeden fellowships

The Wilmot Breeden Group of Companies, whose manufacturing interests include motor vehicle and gas turbine components, hydraulics and electronics, are sponsoring two fellowships, each worth £1,000 per annum, one at the University of Birmingham and the other at the College of Technology. An unusual feature of these fellowships is that the successful candidates will divide their time between the University or College and the company.

The terms of the fellowship awards are so arranged that at any one time there will be a Wilmot Breeden Fellow working in association with the University and another with the College. The fellowships will be advertised every year in March, in 'odd' years in association with the University and in 'even' years in association with the College. Each fellowship will normally be held for a period of two years. A candidate for a fellowship should normally have had two or three years' research or industrial experience. He must be acceptable to the academic authority and would be expected to have an honours degree in a university in the British Commonwealth, a diploma in technology, or an equivalent qualification. An application for a fellowship should outline a two-year investigation or project on which the candidate seeks to work.

Plastic-coated steel sheet

A new British material, Stelvetite, plastic-coated steel sheet, has just been launched by the steel company, John Summers & Sons Ltd., Shotton, Chester. A feature of this new material is that it can be worked and treated as ordinary steel sheet, while its outer surface retains all the characteristics of PVC plastic, produced in a varied range of colours and embossed patterns. Shown in the picture is an example of expanded Stelvetite, magnified to twice the normal size.



Developments at Polish steel centre

The director of building at the Nowa Huta steel works near Cracow, Mr J. Girtler, recently gave some details of developments at present taking place there (*Trybuna Ludu*, February 24, 1958). Work is well advanced on the cold-rolling mill which will, when in full production, yield over half a million tons of plate a year, in thicknesses of 0·6-0·24 mm. The final speed of the rolled sheet in the mill will be 80 km/h. Construction of the first section of the cold-rolling plant will be complete probably by the end of June this year, after which testing will begin. A 370-ton open-hearth furnace is also nearing completion, and should be ready by the end of July, and a third 1,380-ton blast furnace will be completed and start production in mid-July.

EXHIBITIONS

Mechanical handling

The sixth Mechanical Handling Exhibition, which will be held at Earls Court, London, May 7-17, will be the first to show international exhibits. A convention will be held concurrently with the exhibition and will be addressed by speakers from five different industries.

Gauge and tool exhibition

The fifth in the series of gauge and tool exhibitions to be organized by the Gauge and Tool Makers' Association of Great Britain will be held at Olympia, London, from May 12 to 21.

The British Power Press Manufacturers' Association, for which the Gauge and Tool Makers' Association provides office accommodation and secretarial service, will be participating in the exhibition, and a number of their member-firms will have power presses on display.

Mond Nickel at Belfast

Displays and working demonstrations are among the features of an exhibition being held by the Mond Nickel Co Ltd at the Grand Central Hotel, Belfast, until April 18. The exhibition, which is designed to show the latest uses and developments of nickel, nickel alloys and related materials, is open between 10 a m and 7 p m each day.

Displays show corrosion resistance, surface protection, high-magnetic permeability, weldability, controlled expansion, and mechanical properties at temperatures between 900 C and sub-zero. One demonstration shows how an alloy of platinum and rhodium can be used as a catalyst to re-ignite jet engines after failure.

Aluminium in packaging

The eighth symposium organized by the Aluminium Development Association will be held in London on June 12 at the Savoy Hotel. The subject on this occasion will be 'Aluminium in packaging,' and discussion will be divided between two sessions: in the morning, on 'Aluminium as a packaging material'; in the afternoon, on 'The uses of aluminium in particular aspects of packaging.'

The field to be covered is both varied and wide, with interest concentrated on non-returnable containers. Within this scope, eight papers, which will be sent in preprint form to those accepting invitations to attend, will be submitted for aiscussion. Attendance will be by invitation.

Instruments and automation

The Instruments, Electronics and Automation Exhibition, which is being held at Olympia, April 16-25, is again accompanied by a conference.

The subjects to be considered range widely. For example, the chairman of the Committee for the International Geophysical Year, Dr G. E. R. Deacon, who is also director of the national Institute of Oceanography, will deal with 'Progress in the international geophysical year.' Dr S. Kaufman, A E I Ltd Research Laboratory, will consider 'Thermo-nuclear developments—Septre 3.'

Instrumentation for iron and steel, and instrumentation in the petrochemical industry will be reviewed by B. O. Smith, British Iron and Steel Research Association, and S. W. J. Wallis, British Petroleum Co Ltd, respectively.

A new and interesting slant on automation will be given by Dr A. D. Booth, Director, Computation Laboratory, Department of Numerical Automation, Birkbeck College, University of London, in his paper 'Computers—numerical automation.'

fractures are indicated. These are followed by chapters devoted to the effect of specific conditions on the susceptibility of steels to ' brittle fracture,' including the effect of composition, rolling practice, residual stresses, design and welding conditions.

The individual chapters, however, are not all comprehensive in their treatment of particular aspects of the subject. The author has given a fairly extensive survey of the work carried out in his own country, but has omitted reference to several major contributions outside the U.S.A. In the chapter on the theory of fracture, for example, there is no reference to the work of Wells, and in the section on testing several important tests for brittle fracture are not mentioned; thus there is no reference to the Tipper notch tensile or the Van der Veen tests which are strongly favoured as acceptance tests by some important users in the U.K. and on the Continent. Undue weight also appears to be given to a particular interpretation of the Charp tests in the discussion on the effect of metallurgical factors. As an expression of the views of the Ships Structure Committee of the American Academy of Sciences, with whose encouragement the book was prepared, this may be correct, but it is misleading in a textbook on this subject.

In the chapter on manufacturing practice the effect of finishing rolling temperatures is briefly dismissed with reference to laboratory results obtained in the U.S.A. No mention is made of continental work and the author appears to be unaware of the importance attached to rolling conditions by some continental manufacturers of steel plate.

The book contains two chapters at the end which describe a number of ' brittle fractures ' in both ship and non-ship structures. These make interesting reading and do service to the welding engineer by including discussion of several failures found in riveted structures. These chapters, however, have been arranged in catalogue form and do not form part of the logical presentation of the subject. They would have been better as appendices. The book is well illustrated and the author and publisher are to be commended on the clarity of the line drawings.

A. M. SAGE

La Fonderie d'Aluminium en Sable et en Coquille

By R. Irmann. Translated from the German into French by J. Moiroud. 340 pp., 318 figures, Dunod, Paris. Frs. 3,900.

THIS book is destined to be a standard book of reference in the aluminium industry, since it is, at the same time, a didactic textbook for students and a practical book for engineers and founders in the whole field of sand and chill casting of aluminium and aluminium alloys, based on the latest German Standards, DIN 1725/2. It will have a special appeal to the smaller aluminium foundry, forming part of a larger organization, and its clarity, precision and simplicity, supported by a profusion of illustrations, make it most useful to the practical man.

In its twelve chapters this book covers the whole history and practice of aluminium casting, from the raw materials through the whole range of the increasingly important alloys of aluminium up to the limits of the light metal field. Suitability for casting and the troubles met with in casting are dealt with in an early chapter, which will be invaluable to the practical foundry-man. The choice of furnaces and equipment for melting and subsequent heat treatment is fully discussed, as is the choice of suitable fluxes for different cases.

A most important chapter is devoted to the various types of aluminium alloys for casting and the best method to be used for each one of them, not forgetting, as our author reminds us, that ' if the choice of an alloy is left to the founder he will choose the cheapest alloy and the easiest to cast,' to meet the required conditions.

Having chosen the alloy, the technique of casting in sand or in chill is then fully described, followed by surface treatment by mechanical, chemical, oxidizing or coating methods, galvanizing or painting. The question of repair of castings is very fully documented, including the latest methods of welding, such as argon-arc. Then follows heat treatment to increase hardness, with special reference to pistons, and then, stress relieving in castings and in moulds with the furnaces for doing it. Finally, a very full account is given of testing requirements and methods, and of the factors which affect the results obtained. A special section deals with non-destructive testing by X-ray or fluorescence.

As so often happens, the annexes to this book contain a wealth of information: on the most frequent troubles in casting, with a full list of aluminium alloys and the text of the current French Standard Specifications for Light Metal Castings, A.F.N.O.R.

To complete this very valuable book there are exhaustive bibliographies for each chapter, in which the British authorities are well represented, Ruddle, Hudson, Pumphrey, Carrington, Brace, Draper and Jennings among them. The author has given some fifty examples of parts to be made in cast aluminium alloy, with very careful drawings showing how each is to be made, and what results can be obtained, *e.g.* pulleys, automatic balances, handles, gear-boxes, taps, etc.

This descriptive and didactic book is definitely an important and authoritative addition to the literature of aluminium casting. May we expect to see an early translation into English, so as to make all its information available to the wide range of readers in this country, which it deserves to find.

R. W. ALLOTT

General Galvanizing: A Manual of Good Practice

56 pp., 7 illustrations. Hot Dip Galvanizers Association, London. 25*s*.

THE Oxford Dictionary defines ' manual ' as ' a small book for handy use,' and this definition can be justly applied to the work. There are twelve compact sections dealing in logical order with the various stages of the preparation for galvanizing; fluxes and fluxing; the galvanizing process; inspection and finishing. Ash and dross and their related treatments are also covered.

The accuracy and usefulness of the information can be assured by the fact that the recommendations were drawn up by the British Non-ferrous Metals Research Association, in conjunction with the Technical Committee of the Hot Dip Galvanizers Association. Designed as a guide to managers and supervisors in the galvanizing industry, the manual contains a wealth of information, collected in a handy form, with marginal headings for easy and quick reference. A simple method of determining the free acid in hydrochloric acid pickle solution is given and combines with an interesting and useful nomogram to relate the iron content of the pickle liquor to the acid content and density.

The manual costs 25*s*., which, if divided by the number of pages of information, works out at approximately 6*d*. per page—despite the wealth of information contained therein, the price still remains somewhat high.

G. R. MORTON

NEW PLANT

Temperature, Flame-failure and Ignition Control

New additions have been made to the range of temperature and process control equipment by Ether Ltd., Tyburn Road, Birmingham. These include a new temperature recorder, two flame-failure controllers and a temperature controller.

The recorder incorporates a conventional galvanometer, a chart and chart-drive mechanism, recording mechanism, automatic ribbon-mechanism and an automatic station selector and indicator. It records any number of independent temperature points from one to six and has many refinements. The chart has a calibrated width of 6 in. At a speed of 1 in./h., it runs continuously for 30 days and it will also run at speeds of ½ or 2 in./h., if desired. The chart is fed over frontal nylon drive wheels powered by a synchronous electric motor of 220/250 V., which also drives the recording mechanism. Easy loading is ensured by the presence of a hinged-front top-plate which pulls down and gives access to the chart roll. A lightweight 'chopper-bar,' with calibrated scale attached, is fitted above a knife-edged galvanometer-pointer. Through the action of a timing cam and gear-train, the 'chopper-bar' strikes the pointer at given intervals and imprints a small, coloured dot through the ribbon on to the recording chart.

The flame-failure controllers are designed to combat running flame failure in gas- or oil-fired systems. Type 700 is semi-automatic, and Type 701 is a fully-automatic relight unit. A special feature of these controllers is the method of 'seeing' the flame in furnaces. Instead of sensing electrodes, an infra-red-sensitive photo cell, protectively housed and fitted with a toughened glass lens, is used. The photo cell reacts instantly to flame failure when this occurs and an electronic control unit immediately shuts off the fuel supply. The circuit is such that the controllers are sensitive to flame only and ignore radiation within the heating chamber (**1**).

Type 700 unit is designed for manual, electrical ignition of gas- or oil-fired furnaces and has provision for an automatic purge cycle. Type 701 unit is designed for the completely automatic operation of almost all types of gas- or oil-fired furnaces. It has an automatic purge and ignition cycle, thus ensuring that should flame failure occur both pilot burner and main burner are shut off instantly and, after the purging cycle, are automatically relighted.

The new temperature controller, 'Thermal-trol' Type 750, has a wide range, being able to control temperatures between −328° F. and + 1,832° F. (−200° C. and + 1,000° C.) for electrical, steam, gas- or oil-fired apparatus.

The temperature-sensitive element is a platinum-wire resistance, or thermo-bulb, in which the resistance changes in proportion to its temperature, thus causing an unbalanced condition in the a.c. bridge-circuit. A relay opens or closes an electrical circuit, depending on the phase angle of the input voltage to the amplifier. This system is independent of amplifier gain and is extremely stable. No galvanometer is employed, and the instrument is not affected by vibration or ambient temperature.

1 *Ether flame-failure controller*

High-frequency 6-kW. Induction Generator

Equipment specially designed for silicon refining and similar processes where a very high work coil kVA. is essential has been introduced by Radio Heaters Ltd., Eastheath Avenue, Wokingham, Berks. The C50/SR 6-kW. induction equipment operates at a nominal frequency of 5¾ Mc/s and will develop a peak voltage in excess of 4,500 V. across a work coil of 0·5 μH. By using a higher frequency than is normal for induction heating, it is possible to achieve a high work coil kVA. without using a generator of high power. The relative efficiency of the process is, therefore, high and the capital cost low. The equipment is designed for use with work coils of between 0·3 and 1·0 μH. As the work coil forms the actual tank coil of the oscillator, the operating frequency will vary over a range of 3·5 to 6·5 Mc/s.

A manual power output control is provided in the form of a separate self-contained voltage regulator. This feeds the primary of the high-voltage transformer and provides the facility of varying the anode voltage fed to the oscillator valve down to 25% of the normal value of 5·5 kV. d.c. This regulator can also maintain, if desired, a constant output at any predetermined voltage setting over its control range. An additional facility can be provided if required whereby the output of the generator is reduced almost instantaneously from 6 to 1 kW. This is achieved by initially by-passing the voltage regulator and then by a contactor sequence switching in the regulator which has previously been set for reduced voltage. This facility is most useful for initiating the process cycle when silicon refining. Providing the silicon rod to be processed is not of a high purity, it will be possible to heat the rod from cold without the necessity for pre-heating by conduction or other methods. Once the rod commences to heat, however, its resistance decreases rapidly, which results in an accompanying sudden increase in temperature rise. By the depression of a push button the voltage regulator can be switched into circuit, thereby instantaneously reducing the power input to the silicon to a predetermined value to match the change in the characteristics of the material and the traverse speed for refining.

Automatic Controller Failure Signal

An automatic controller failure signal and safety unit has been developed by Foster Instrument Co. Ltd., Letchworth, Hertfordshire. It provides a mechanism that automatically and periodically checks the functioning of potentiometric self-balancing controllers by sending through the signal generating, measuring and balancing system a periodic test signal which, if it fails to get through due to any electrical or mechanical fault in the system, causes a warning signal to be given and, if required, automatic shut-down or safeguarding action to be taken. The frequency and strength of the test signal can be set to suit the 'run-away' time of the controlled process and the balancing speed of the controller. The device is fitted with an alarm which functions should its own prime mover fail.

Electrolytic Polisher Specimen Preparation

An electrolytic polisher based on apparatus developed by the Atomic Energy Research Establishment, Harwell, is being marketed by Shandon Scientific Co. Ltd., 6 Cromwell Place, London, S.W.7. The original apparatus has been described by Sykes, Haddrell Haines and Mott (*J. Inst. Metals*, 1954-55, **83**, 166).

The polisher prepares specimens for immediate microscopic examination. In operation, electrolyte is drawn through a centrifugal pump and is forced through a series of holes where it contacts the specimen as a constantly rotating, continuously renewed liquid column, to ensure a perfect polish and quality finish without flow lines. Cold working and false deformation structures are eliminated, and specimen preparation is considerably simplified.

The polishing deck, mounted on rigid PVC, is a self-contained unit resting on the electrolyte tank, and contains the pump, specimen clamp and electrolytic cell. The power supply has separate d.c. outputs and controls for manual and automatic polishing and etching. Additional output terminals provide facilities for beaker etching when required. On ' manual,' all switches are independently and separately controlled by on/off switches. For operation on ' automatic,' the time switch is set to the required polishing period (within a range of 1 to 90 sec.). At the end of the period, both the pump and the d.c. are automatically switched off. Electrolytic etching can be carried out as part of the operation by switching to ' etch ' during the last seconds of the cycle.

Surface Sealing Metal Treatment Baths

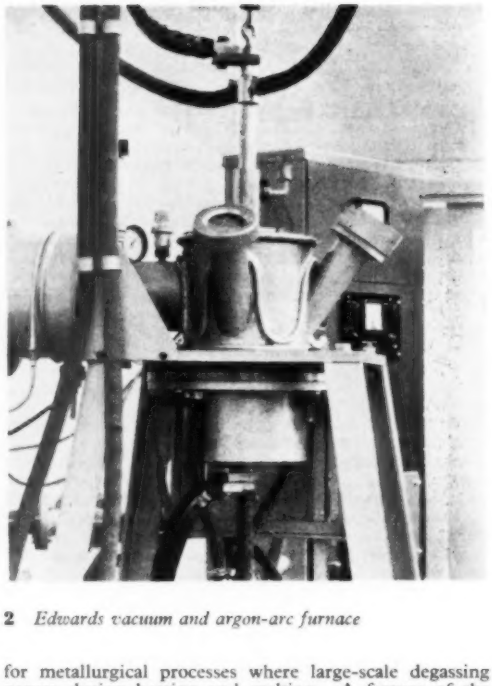
The Paints Division of I.C.I. Ltd. has introduced a new process—the ' Serseal ' layer process (British patents applied for)—for eliminating fumes and steam from aqueous metal treatment baths and for reducing heating costs.

The process seals the surface of the processing liquid in the bath with a layer of inert material and this not only checks fumes and steam but also reduces the amount of heat needed to keep the bath at a working temperature. By using ' Serseal,' fuel economies of up to 75% have been recorded under production conditions. Working conditions are improved and shop condensation and structural corrosion are retarded. The process can be operated without alteration to the processing tank. An additional advantage is that, owing to the reduced heating requirements, heating units need much less frequent cleaning, and maintenance costs are reduced.

' Serseal ' was developed primarily for use in baths producing heavy phosphate coatings—such as those employed in the I.C.I. ' Granodine ' 101 process. It has now been extended to other ' Granodine ' processes. Certain precautions are necessary where work is to be subsequently painted. Alternative grades are available to suppress acid fumes and spray from pickling tanks and to conserve heat in alkaline paint stripping vats.

Vacuum/Argon Arc Laboratory Furnace

A laboratory-scale arc furnace for vacuum melting has been introduced recently by Edwards High Vacuum Ltd., Crawley, Sussex. The furnace is a compact and versatile unit, capable of being used for both consumable and non-consumable electrode work. The dual-purpose version of the furnace is pumped by a 9B3 booster vapour pump backed by a 1SC450 rotary pump displacing 15 cu. ft./min. These booster pumps are specially designed for metallurgical processes where large-scale degassing occurs during heating and melting. A feature of the pump is its ability to work against backing pressures as high as 3 mm. Hg, thus enabling it to be used in the pumping cycle when the efficiency of the rotary pump is still high. The unbaffled speed of the 9B3 is 900 l./sec. at working pressures as low as 0·004 mm. Hg and it has a maximum gas throughput of 18,000 l. microns/sec.



2 *Edwards vacuum and argon-arc furnace*

If required solely for non-consumable electrode operation, the high-speed booster pumping system is not necessary, as the furnace will operate in a low-pressure argon atmosphere. To maintain purity in melting, however, a smaller pumping system is provided consisting of a model 203 oil diffusion pump capable of attaining an ultimate vacuum of 5×10^{-6} and having an unbaffled speed of 80 l./sec. This is backed by a ' Speedivac ' 1SC150 rotary pump displacing 5 cu. ft. min. Vacuum measurement in the backing line is provided by B2 Pirani-type vacuum gauge which can also be used as a leak detection unit using the hydrogen/Pirani method.

High-speed Electronic Recorder

The Mark 2A electronic ' Multelec ' recorder, developed by George Kent Ltd., Luton, Bedfordshire, for the atomic energy industries, is now generally available. Its applications are: temperature measurement (thermocouple or resistance thermometer); direct millivoltage recording; for industrial measurements depending on a radioactive source and ionization gauge, such as of level, material thickness, density, etc.; and for research work.

This instrument has been designed primarily as a single-point indicating recorder, enabling measurement to be made at high speed. Three different types of built-in amplifier are available, the type used depending on the application.

PEOPLE

VISITING SWEDEN this month to address the Royal Swedish Academy for Engineering Sciences is **Mr Stafford Beer,** head of United Steel Companies' department of operational research and cybernetics. Mr Beer has been invited by Prof Edy Velander, director of the Swedish Academy, to give talks both on operational research and cybernetics on April 24 and 25. A day will be devoted to each subject and the proceedings will conclude with a seminar at which the leading Scandinavian exponents in this field will get together round the table with Mr Beer.

During the remainder of a week's stay in the country under the patronage of the Swedish State Council of Technical Research, Mr Beer will have an opportunity of seeing what progress Swedish industry—and the iron and steel industry in particular—is making in automation generally.

There is a considerable oversea demand for his services as a lecturer on cybernetics, the science which seeks to reproduce some of the characteristics of the human brain from inanimate matter. In the last two years, he has addressed large gatherings in France and Belgium and there are invitations outstanding from Australia and the United States. In addition, Mr Beer is a prophet not without honour in his own country: his George Bray Memorial Lecture to the Institution of Production Engineers on 'The scope for operational research in industry' last year continues to arouse interest—and requests for further lectures.

Mr George Wright, London manager of the Incandescent Group of furnace engineers, Smethwick, left on March 31 for an extended market investigation in India. The Incandescent Group has had a long association with India, and Mr Wright will report on the new openings for capital goods in this rapidly expanding market.

Mr F. G. Brewer, O B E, who has been secretary to the Gas Council since its formation in 1948, will retire from that office at the end of September. The council has appointed as his successor the chief accountant of the council, Mr Wilfrid Bailey, F S A A.

Metropolitan-Vickers Electrical Co Ltd announces that **Mr N. R. D. Gurney,** A C G I, M I E E, is appointed sales manager, Plant Department. Formerly chief engineer, Electrical General Engineering Department, Mr Gurney succeeds Mr R. J. Cochran, who is seconded to special duties.

Mr Gurney received his technical education at the City and Guilds Engineering College of the Imperial College of Science and Technology, and joined the company as a college apprentice in 1926. After short periods as junior engineer on industrial control and rolling-mill equipment, he became liaison engineer for technical interchange with associated companies, and in 1931 he was awarded an I G E Fellowship to study steelworks electrical engineering at the General Electric works at Schenectady. In the following year he returned to Plant Department as rolling-mill engineer.

During the war, Mr Gurney became engineer-in-charge (and later acted as assistant superintendent) of the M-V Gun Carriage Department, and in 1943 he was attached to an Admiralty delegation at Washington. He returned at the end of the war to the rolling-mill engineering section of Plant Department, and in May, 1951, he was appointed chief engineer, Electrical General Engineering.

Uddeholm Ltd, the British associates of Uddeholms AB, Sweden, have appointed **Mr S. A. Comley** as London area manager, Tool Steel Division.

Mr Comley, who has been the firm's tool steel representative in the Birmingham territory for the last five years, will operate from 6-10 Dean Farrar Street, Westminster, London, S W 1. His position in Birmingham will be taken by Mr A. G. Shaw.

Pro-chancellor of the University of Sheffield for 1958-59 is **Prof Arthur George Quarrell,** the university's Professor of Metallurgy and head of the Department of Metallurgy. Prof Quarrell, who is 47, was educated at the College Secondary School, Swindon, the Imperial College of Science and Technology, and Sheffield University, where he held his first appointment as assistant lecturer in the Department of Metallurgy.

He became lecturer in the department in 1940 and five years later joined the British Non-Ferrous Metals Research Association. He was senior metallurgist for six months and was appointed research manager in March, 1946. Prof Quarrell returned to Sheffield in 1950 as Professor of Physical Metallurgy and Dean of the Faculty of Metallurgy.

He is the author of 'The physical examination of metals,' and a number of papers in the proceedings of the Royal Society and the Physical Society, and in the journals

Prof A. G. Quarrell

of the Institute of Metals and of the Iron and Steel Institute. He was appointed a member of the Nuclear Energy Committee of the Institute of Metals in 1955.

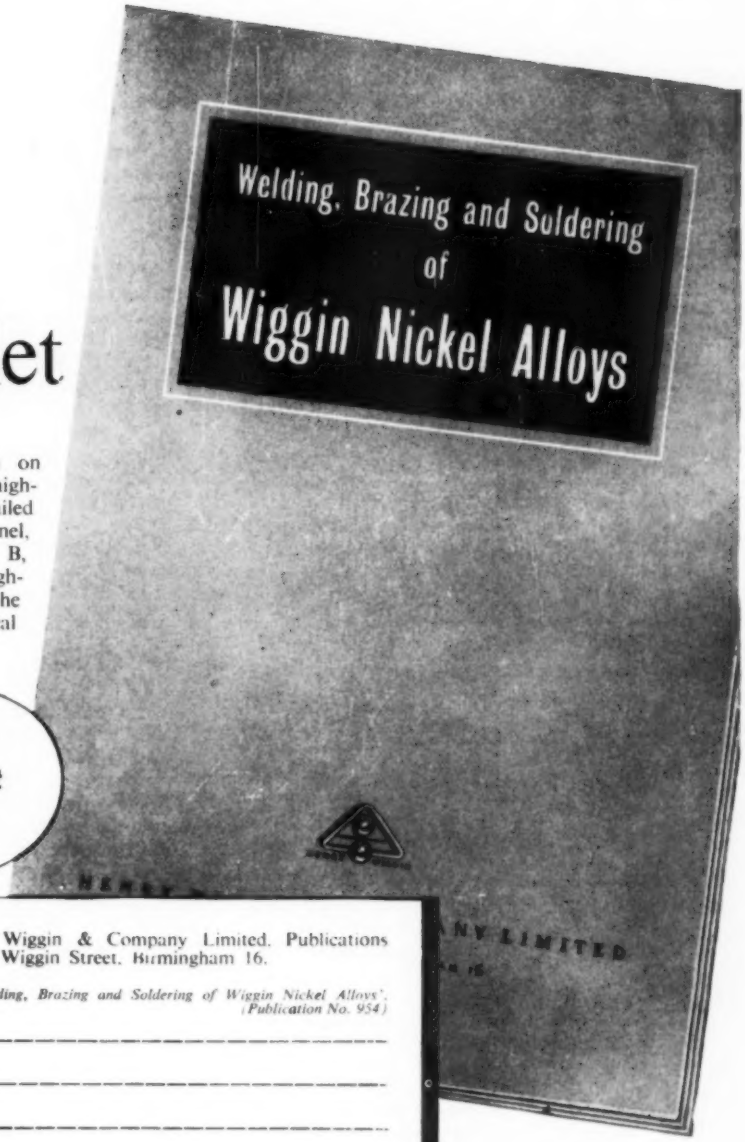
Dr P. H. Sykes, a director of the British Oxygen Co Ltd, has been elected chairman of the Low-temperature Group of the Physical Society. The Group was formed in 1946 to promote low-temperature interest.

After 21 years with the General Electric Co Ltd, which he joined as a graduate apprentice at Bradford in 1937, **Mr F. P. Liebert** has been appointed works manager of the company's establishments at Rugby and Whetstone, near Leicester. He will be responsible to the general manager, Rugby and Whetstone, Mr E. M. Price.

Mr S. A. Bergen, M B E, A M I E E, has been appointed chief development engineer of the Cambridge Instrument Co Ltd.

This new Booklet

gives full information on methods of joining Wiggin high-nickel alloys. It includes detailed recommendations for Monel, nickel, Inconel, Corronel B, the Nimonic series of high-temperature alloys and the Brightray series of electrical resistance materials.



Copies will gladly be sent on request

To: Henry Wiggin & Company Limited, Publications Department, Wiggin Street, Birmingham 16.

Please send me a copy of 'Welding, Brazing and Soldering of Wiggin Nickel Alloys'. (Publication No. 954)

*Name*_____

*Address*_____

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MT

HENRY WIGGIN & COMPANY LIMITED *WIGGIN STREET · BIRMINGHAM 16*

TGA 687

Stainless-steel coated plates

France goes into production

THE GREAT EXPANSION in the petroleum industry, the chemical industry and the cellulose industry has led to increased use of stainless steels, owing to the attack of the products in question on ordinary steels and to the requirements of purity in the manufacturing processes. New openings have been presented for these steels, owing to the extension in their use for new kinds of plant or for larger numbers and larger sizes of existing plants. This tendency has been helped by the widening range of stainless steels available and of the ever-growing possibilities which they present in solving the new problems of resistance to the most varied kinds of attack.

Technical and economic difficulties

The use of stainless steels has, however, met with difficulties both in the technical and in the economic fields. The production of heavy stainless-steel plates is limited by existing facilities for manufacture and rolling, whereas industry is moving towards bolder designs calling for thicker and larger plates. To the already high price of these steels, and to the difficulties met with in production, there has to be added the particularly high cost of fabrication, which is especially due to the welding which has to be done to make up for the lack of sheets of the required shape and size.

A coated plate is essentially made with a basis plate of carbon steel, or a weldable low-alloy steel. On one or both faces of the plate is fixed, in close contact, a plate of stainless steel or stainless alloy. The basis plate gives to the built-up plate its own properties of mechanical strength, and the plating, even though relatively thin, gives protection to the construction against corrosive attack. The fully continuous contact between the two steels gives a very great resistance and allows of the compound plate being incorporated into constructional work like a homogeneous plate, so long as certain precautions are taken.

For a long time, these coated plates were not manufactured in France, as they require very extensive and powerful equipment for making, rolling and heat treatment. Now, however, according to an article in *La Metallurgie*, November, 1957, this is no longer so, and coated plates of French manufacture can compete successfully with similar products from elsewhere.

The method of manufacture of plates of usual thickness is as follows:

Rough-rolled plates of the two metals are taken with their thicknesses appreciably in the same proportion as they are to be in the final coated plate, bearing in mind the loss in working of each of them.

The faces of the stainless steel, which will come into contact with the basis plate, are covered with an electrolytic deposit. A symmetrical assembly in the form of a sandwich is made, comprising, in the middle, two plates of stainless steel separated by a refractory coating to prevent them sticking to one another during rolling, and, on the outsides, two basis-steel plates. Precautions are taken to prevent the plates from moving in relation to one another during rolling, and provision is made for handling the composite article.

The semi-product so obtained is heated and rolled practically like a one-piece homogeneous plate. Under the effect of temperature, heavy pressure and working, set up by rolling, the cohesion between the two steels becomes perfect, to such a degree that the most severe treatment during forming does not cause any separation. The coated plates thus rolled are then separated from one another by cutting off the edges and they are then finished like one-piece products.

If it is desired to produce plates protected on both faces with stainless steel, called two-face coated plates, the method follows on the same lines but is adapted to that particular product.

Choice of steels

The grades of steel most commonly used for basis plates are carbon welding steels, extra-soft or semi-hard. The use of other welding steels with special properties can also be envisaged, for instance, high elastic-limit steels, creep-resisting steels, non-ageing steels and low-temperature-resisting steels. The coating plates are ferritic or austenitic stainless steels, chosen according to the use to which the coated plates are to be put.

Mechanical tests generally applied to one-piece plates are also carried out on coated plates. Tensile tests and results are taken in the usual way as for one-piece plates, *i e* elastic limit, breaking strength, elongation, and reduction of area.

continued on page 178

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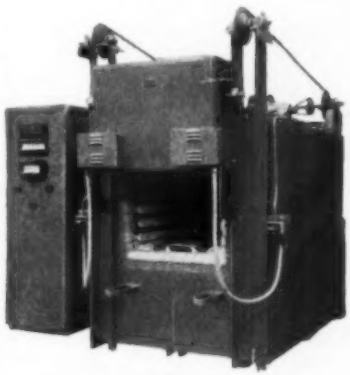

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Stainless-steel coated plates

concluded from page 176

Bend tests can be taken with the plating outside, that is to say in expansion, which allows of measurement of capacity for deformation of the coating plate; or with the plating inside, that is in compression, which allows one to measure cohesion between the plates being tested. Impact tests, which would not have much significance for a composite plate, are generally taken on the basis metal only. A special test, called the shearing test, can also be applied. The plating is chamfered down, leaving only a small tongue to which a known stress is applied. The shearing stress, which the area of juncture between plating and basis metal must withstand, must be above a guaranteed minimum.

Constructional applications

Although they are heterogeneous, coated plates behave almost in the same way as a homogeneous product. They can, therefore, be easily worked, deep pressed, bent, and cut with the blow-pipe, provided certain simple precautions are taken. They can be shaped much more easily than can one-piece stainless-steel plates.

Welding of coated plates does not call for any special precaution in regard to pre-heating beyond those which are taken with the basic steel itself, having regard to its composition and thickness and on condition that the electrodes are suitably chosen. For the basis steel, the rule is to use those electrodes which would be used for a one-piece plate of the same grade. If an alloy steel is being used, the electrodes must deposit a metal of similar nature.

For welding the plating of stainless steel, the rule is to use a filling metal richer in alloying elements than the plating metal, particularly in chromium. This is to offset the dilution which might be caused by the basis metal.

The reasonable use of coated plates must be based on a study of each particular case, which must be made with the object of saving expense, both on the price of the prime materials and on the cost of construction.

The complexity of the fabrication method makes it of interest to obtain plates of adequate weight, and the best results are obtained by rolling each thickness of plate into the largest sizes possible. The process of manufacture, described above, leads to two identical plates being produced and this should be taken into account when plant constructional details are being considered.

Reduction in thickness, and the use of large plates, reduce the section and the length of welds, and so reduce consumption of electrodes, with a consequent reduction in cost of production. A wise choice of grade and thickness of plating reduces the use of welding electrodes rich in alloying and particularly expensive elements.

The choice of the thickness of plates to be used for pressure vessels, working at room or fairly low temperatures, is decided in accordance with the tensile strength, or rather the elastic limit, of the basis steel in relation to working conditions. Steels with high mechanical characteristics can be envisaged if their higher price is compensated for by a reduction in thickness, and so of weight involved, and by the easier way in which they can be fabricated and erected as a result.

In the case of plant working at high temperature, the basis metal will be chosen according to its capacity of standing up to as high working conditions as possible.

The plating grade of steel must be very carefully chosen, as must also be its thickness, which is an important factor in its price. The latter must be very carefully decided upon and experience has shown that it is generally better to keep it within the limits of 8 — 20% of the total thickness. As a first approximation, plating of the order of 15% can be used for sheets less than 20 mm ($\frac{3}{4}$ in) thick. Above that, it is reduced in most cases to about 10%, with a maximum of 3 to 4 mm ($\frac{1}{8}$ in).

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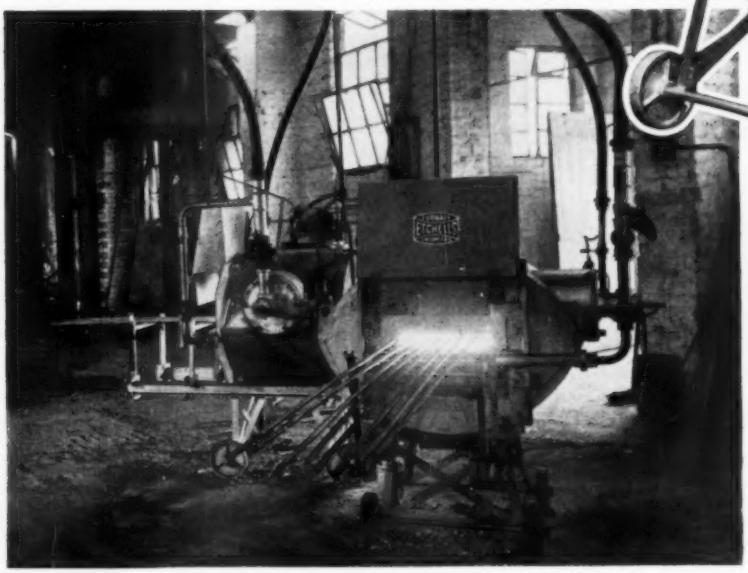

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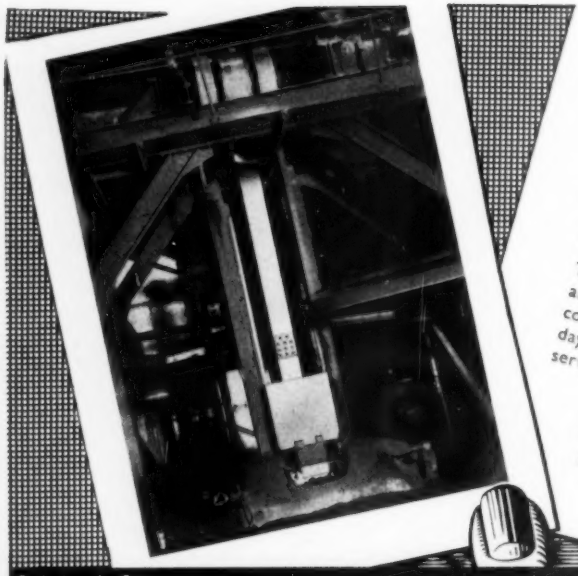

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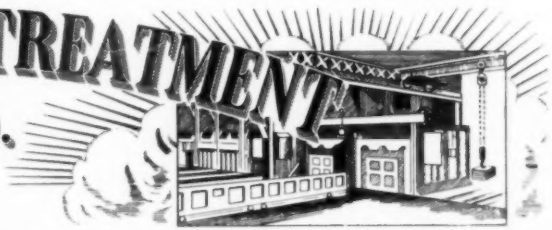

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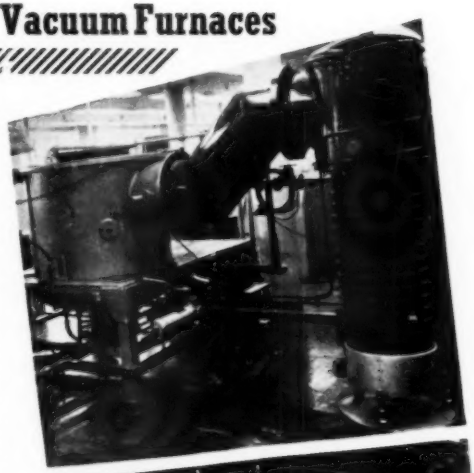

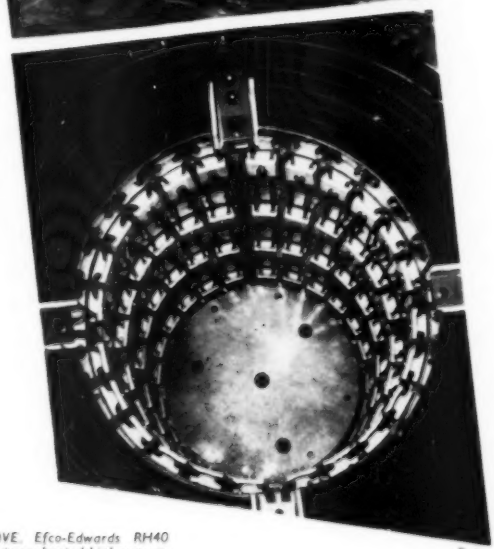

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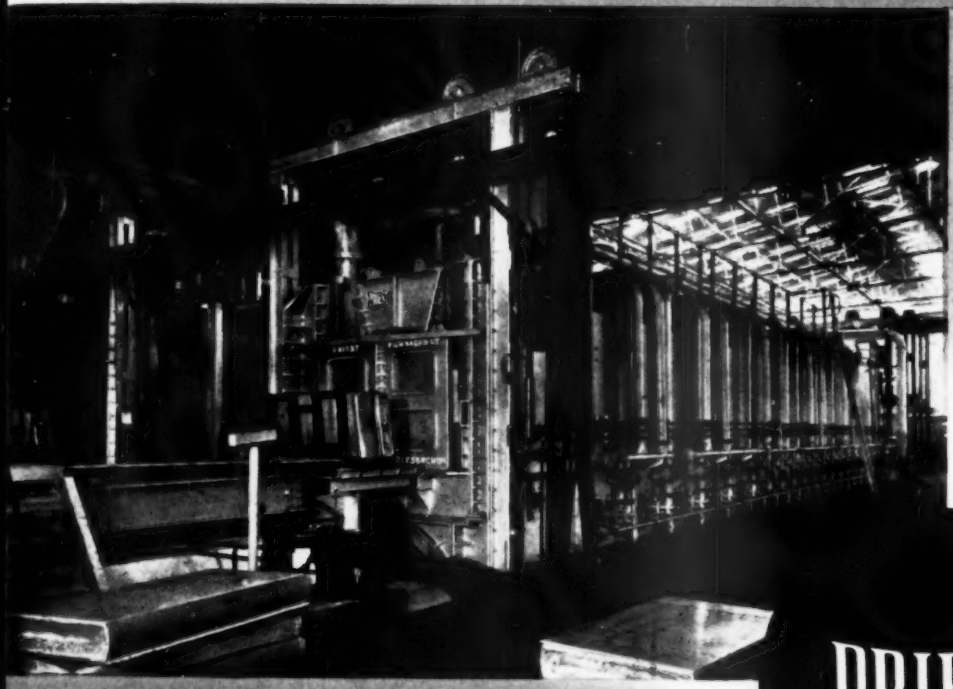

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